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NATIONAL PLAN FOR DEVELOPMENT OF THE MICROWAVE LANDING SYSTEM ---ETC(U)
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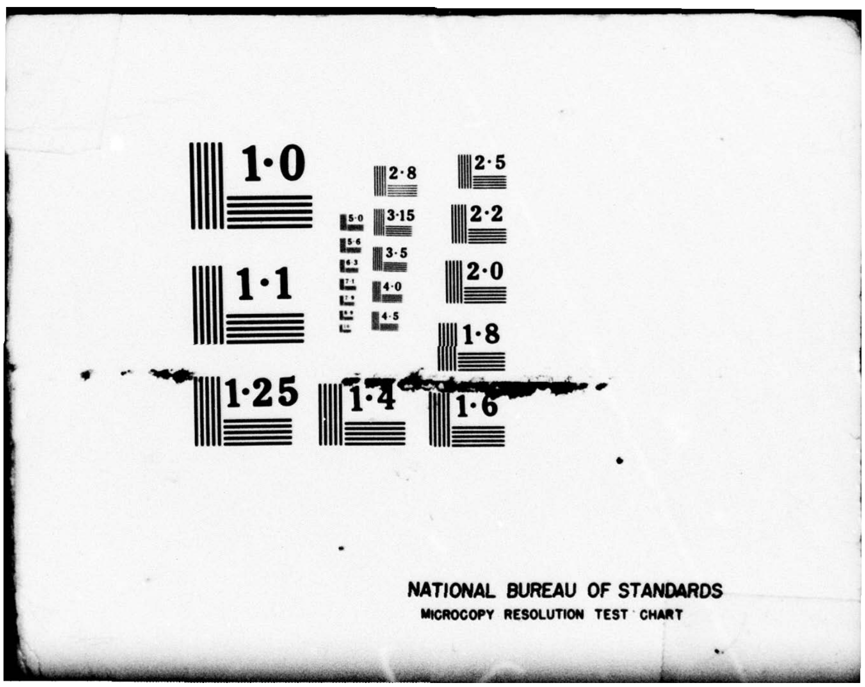
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NATIONAL PLAN
FOR DEVELOPMENT OF THE

MICROWAVE LANDING SYSTEM

TASB
MLS

JUNE 1978 UPDATE

NOTICE

Technical Report Documentation Page

1. Report No. 14 FAA-ED-Ø7-2A	2. Government Accession No.	3. Recipient's Catalog No. 11

4. Title and Subtitle

6

National Plan for Development of the Microwave Landing System - June 1978 Update.

5. Report Date

June 1978

6. Performing Organization Code

7. Author(s)

8. Performing Organization Report No.

9. Performing Organization Name and Address

Federal Aviation Administration
Department of Defense Systems Research & Dev Service
National Aeronautics and Space Administration
Washington, D.C.

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

12) 98p.

Department of Transportation
Washington, D.C. 20590

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

An updated plan for the development of an interoperable civil/military microwave landing system (MLS) is presented. The original plan ~~prepared in July 1971~~ delineated a five (5) year program of integrated activity deemed necessary to provide a MLS that meets the wide range of user operational requirements. ~~set down by RTCA SC-117~~. The substance of the work and the goals achieved under the initial plan have occurred essentially as planned except for the schedule. The TRSB (Time Reference Scanning Beam) technique selection was made about one year later than originally planned and considerable time and resources were devoted to ICAO activities that were not initially envisioned. ~~in 1971~~. A major milestone in the MLS program was achieved in April 1978 at the All Weather Operations Divisional meeting of ICAO, when the U.S. TRSB system was selected to be the standard system for international civil use as a replacement for ILS.

17. Key Words	18. Distribution Statement
Microwave Landing System National Plan for Development of the MLS Approach and Landing System	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	97	

Form DOT F 1700.7 (8-72)

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METRIC CONVERSION FACTORS

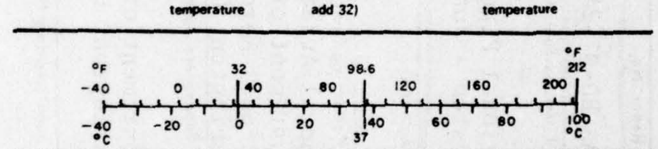
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The National Plan for the Development of the Microwave Landing System, prepared in July 1971, delineated a five year program of integrated activity deemed necessary by a joint DOT/DOD/NASA planning group to provide a Microwave Landing System (MLS) that meets the wide range of user operational requirements. This update of the initial National Plan (1) describes the progress that has been made toward accomplishing the objectives of the initial Plan, (2) discusses changes to the initial Plan, and (3) outlines the activities required to complete the development.

The DOT, DOD and NASA continue to strongly support the objectives of the Plan and agree to conduct the tasks and apply the funds as outlined herein, subject to reconsideration should subsequent events disclose a need for program modification or reorientation.

29 JUN 1978

Deputy Secretary of Transportation

Assistant Secretary of Defense
(Communications, Command, Control and Intelligence)

Associate Administrator for Aeronautics and Space Technology,
National Aeronautics and Space Administration

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SUMMARY

This document provides an update to the National Plan for Development of the Microwave Landing System published in July 1971. It describes the progress that has been made toward accomplishing the objectives of the original Plan and outlines the activities required to complete the common civil/military development program as planned. It discusses several significant changes to the original Plan with the rationale for the changes, and includes a discussion related to the implementation of the system.

The original Plan delineated a five year program including two major complementary efforts: (1) an Industry Development Program employing a three-phase contracting procedure designed to produce prototype equipments, and (2) a series of interrelated and interdependent Supporting Government Programs to be conducted concurrently by the individual participating agencies (i.e. DOD, DOT, and NASA) either in-house or with separate contract support.

Phases I and II of the Industry Development Program were conducted essentially as planned and completed in December 1974, approximately eleven (11) months behind the original schedule. This work completed the system development of the TRSB technique and its associated signal format. Phase III (Development, Flight Test, and Evaluation of Prototype Systems) has been completed for only two system configurations (Basic (Narrow) and Small Community). Prototype development activity on the remaining civil systems (Basic (Wide) and Expanded) and all military systems was held up pending the ICAO decision on an international standard. This updated plan describes the activities now planned to complete the prototype development of these systems.

The Supporting Government Programs part of the original plan was comprised of a very comprehensive list of specific tasks to be accomplished by, and funded by, each of the participating agencies. This program was restructured following the FY73 House Appropriations Committee Hearings on the DOD budget, wherein limitations were placed on the use of DOD funds for this purpose. Most of this activity has now been completed.

This updated plan identifies the work yet to be accomplished; principally this is the testing and evaluation of the remaining prototype system configurations.

There have been several significant changes to the original 1971 development plan:

a. Redefinition of System Configurations

b. Congressional actions which restricted the use of DOD funds for certain MLS supporting program activities

c. Assignment of Program Management responsibility for the development of the military configurations to a Military Lead Service.

Probably the most significant milestone in the MLS development program was the selection of the U.S./Australian TRSB system as the new international standard approach and landing guidance system by the International Civil Aviation Organization (ICAO) on April 19, 1978. The intense competition that preceded this selection had a major impact on the development program in terms of schedule delays, unanticipated test and demonstration activity, and some added costs, but also served to establish confidence in the technical maturity and suitability of the TRSB system for broad operational deployment.

Planning is now underway to provide an orderly transition from system development to system implementation. The MLS program will require a substantial capital investment over a number of budget years. Therefore, the FAA is preparing a Transition Plan for MLS to provide assurance that any implementation decision is fully supported by essential evaluation and documentation. For the MLS program there are a number of transition activities that are planned. One of those under consideration is a Service Test and Evaluation Program (STEP) in which the MLS would be demonstrated to various user groups. At the same time, this program would serve to develop operational procedures in the field. Other activities will be to conduct studies to develop logistic concepts, implementation alternatives, schedules, etc. All of these transition activities within the U.S. will be complementary to and conducted in harmony with the ICAO efforts to complete the international process of standardization. Military transition planning will necessarily be predicated on the civil implementation schedule and the successful completion of the Engineering Development (ED) phase for the military configurations.

A current description of the TRSB system is contained in Appendix A of this Plan; a glossary of abbreviations used in this Plan is contained in Appendix B.

1.0 INTRODUCTION

In this introduction to the update of the National Plan for Development of the Microwave Landing System the following topics are discussed:

- The purpose of this document.
- The need for a national MLS program.
- A summary of progress in implementing the Development Plan.

1.1 Purpose

The purpose of this document is to update the National Plan for Development of the Microwave Landing System, published in July 1971 (Reference 1), and to describe the joint DOT/DOD/NASA effort required to complete the prototype development program.

This updated plan will:

- Discuss changes to the July 1971 Plan
- Outline the MLS development effort planned by the participating agencies to complete development activity
- Provide data on funding resources required
- Discuss the ICAO international standardization activity
- Discuss transition planning for the new landing system.

1.2 Need for a National MLS Program

The Instrument Landing System (ILS) became the world standard civil landing guidance system in 1949. For nearly 30 years it has served the aviation community well and, in many cases, still does. However, the standard ILS has the following limitations:

- First, improved performance of aircraft and increased air traffic density have placed new demands on approach and landing systems, and the ILS technique, in spite of modern improvement, does not meet some of today's requirements and certainly cannot meet the challenge of tomorrow's aviation.

- Second, ILS cannot be used at many runways because of unfavorable terrain contours.
- Third, ILS cannot serve as a tactical system for military use.
- Fourth, ILS is not adequate for VTOL and STOL operations into confined areas.
- Fifth, ILS is limited to 40 available frequency channels, which would seriously limit necessary expansion of facilities in congested areas.

Recognizing these limitations and the need to provide a common civil/military interoperable landing system, the Radio Technical Commission for Aeronautics (RTCA) Special Committee SC-117 was formed in 1967 to consider this problem.

This committee, consisting of several hundred aviation experts, began its work by defining and obtaining agreement on the operational requirements for a new system. This was a major achievement and required considerable analysis and discussion by the diverse aviation user groups to reach a single statement of requirements that would meet the approach and landing needs of all aircraft and airports. The nature and scope of the statement of operational requirements can be obtained from the following abstract from the Committee's work where it was addressing the broad objectives of a new system.

A new microwave landing system is needed to:

- Provide a high integrity precise signal in space, which is insensitive to a physicially dense airport environment;
- Permit all weather operations with an extremely high degree of safety;
- Provide for a common civil/military system in accordance with national policy;
- Provide for low cost versions which will permit the extension of service to low density airports on an economical basis;
- Fulfill the operational needs of V/STOL aircraft for approach and landing services;
- Provide a flexible guidance system which will aid in noise abatement;

- Provide the capability for generating curved approaches to runways as a means for increasing airport capacity;
- Permit less separation (2500 feet) of parallel instrument flight rules (IFR) runways;
- Provide for tactical military versions of the system on a compatible basis;
- Provide a system design which will be internationally acceptable as a replacement for the ICAO standard VHF/UHF ILS and will meet worldwide requirements.

The next task of the Committee was to develop a concept and signal format to satisfy the operational needs of all classes of users. The Committee assessed both air-derived and ground-derived techniques and concluded that air-derived systems had the greatest potential. Among the air-derived concepts analyzed, the Scanning Beam and Doppler scan techniques were considered the primary candidates for further development. These recommendations became the basis for the July 1971 National Plan to develop a new Microwave Landing System (MLS).

1.3 Progress in Implementing the National MLS Development Plan

The original National Plan was comprised of two interdependent, complementary activities; (1) a Government funded, industry oriented System Development Program designed to produce prototype MLS equipment and production specifications, and (2) a concurrent series of Supporting Government Programs to be undertaken by DOT, DOD and NASA.

1.3.1 System Development Program

The System Development Program was structured as a three-phase program to explore all technology applicable to the MLS and to proceed with the development of only those approaches that appeared most promising. Technical evaluations at major milestones throughout the program and a thorough assessment at the end of each major phase of the program would narrow the range of technology and competition for further development. In late 1971, technical

proposals were received from nine different contractor teams and subjected to analytical evaluation. Six of these teams were awarded contracts in February 1972 to participate in Phase I (Technique Analysis). The final Phase I reports from these six teams and their proposals for Phase II revealed that four of the teams had selected a scanning beam technique and two had selected Doppler. The assessment of these proposals resulted in the award of four contracts in March 1973, to enter into Phase II (Feasibility Demonstration). Two of the contracts were for scanning beam designs and two for Doppler scan systems. In this Phase each of the four contractor teams finalized their system designs and produced feasibility hardware models for testing and evaluation. After a most comprehensive assessment at the end of Phase II, the Time Reference Scanning Beam (TRSB) technique for angle guidance was selected to be further developed in Phase III, and submitted to ICAO as the U.S. candidate for international standardization. The Distance Measuring Equipment (DME), which is an integral part of the system, had not been completely defined at this point and was to be investigated/developed as part of the prototype hardware development in Phase III for each configuration.

Contracts for Phase III (Prototype Development, Test and Evaluation) were awarded in July 1975 to each of the two Phase II scanning beam contractors for one Basic (Narrow) and one Small Community system. Other MLS configurations designed to meet the full range of needs for all civil and military users are scheduled to be developed in the next several years as discussed herein.

The System Development (i.e., the development activity leading to the selection of the TRSB technique and signal format) was accomplished in Phases I and II of the program. The development, flight test and evaluation of competitive feasibility models of each system technique, augmented by supplementary development work accomplished in connection with the preparation of the U.S. proposal to ICAO, confirmed the feasibility of the final system design and established the signal format architecture.

The Prototype Development (Phase III) is to demonstrate that each of the selected configurations, when produced in prototype hardware, can satisfy the operational requirements for which it is intended. The two configurations

that have been completed (Basic (Narrow), which will be the most widely used system; and the Small Community, which is the least sophisticated system) have confirmed the adequacy of the system design and signal format for these applications. What remains to be done is the development and testing of the prototypes of the more sophisticated Category III civil system and all of the various military configurations to prove suitability for their unique operational requirements.

Figure 1-1 is the complete development program schedule.

1.3.2 Supporting Government Programs

The objectives of the supporting Government programs were threefold:

- First, to conduct independent investigation to: broaden the base of technical knowledge, solve critical problems and better enable the Government to perform comprehensive program evaluations and make necessary technical decisions.
- Second, to investigate the application of MLS to user needs, such as Air Traffic Control interfaces, selectable and curved flight paths, aircraft displays and utilization of receiver outputs, and unique military applications such as ship deck motion.
- Third, to conduct flight tests and evaluations to validate the adequacy of the selected MLS to meet the diverse user requirements.

The original National Plan called for each Supporting Government Program task to be accomplished and funded by the agency assigned responsibility for that task. As a result of Congressional review of the FY73 budget, new guidelines were established for funding this effort. In effect, the Congressional guidelines were that the FAA should provide funds for the "development" program and that DOD could appropriately fund for only those MLS tasks that were related to testing and application of the FAA-developed systems to meet peculiar military operational requirements.

The remaining efforts for each of the participating agencies are: (1) to continue those tasks designed to assure suitability of the selected technique to meet their unique user requirements and (2) to conduct the testing and

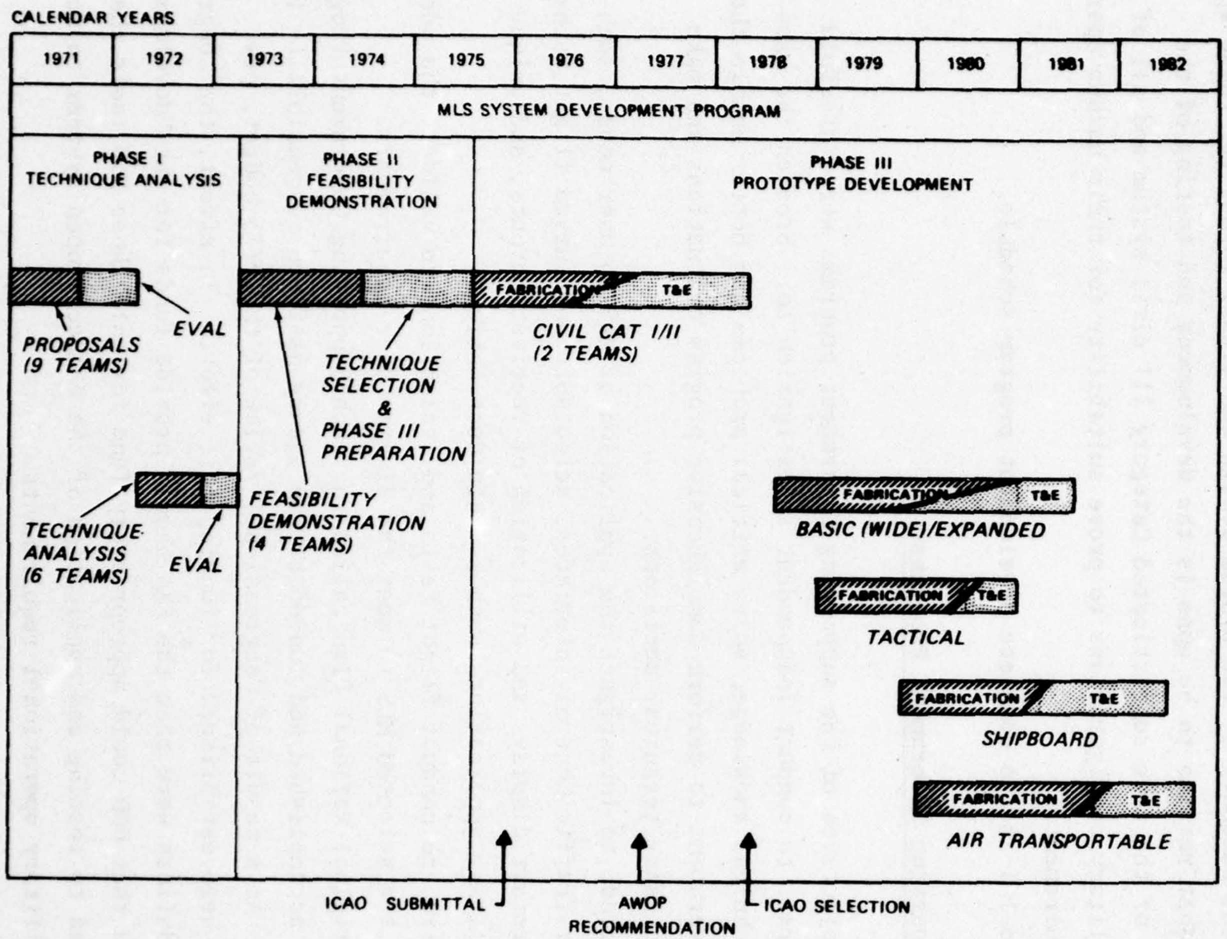

Figure 1-1. MLS System Development Program Schedule

evaluation of prototype systems designed to meet their peculiar operating requirements.

1.3.3 The Evolution of the MLS Design Concept

As a result of the broadly-based MLS development program, a system concept evolved, which is different in some respects from that postulated by the RTCA SC-117 activity which formed the starting point for the national MLS program. The purpose of this section is to identify the ways in which the TRSB MLS design is different from the proposed concept described in the 1971 National Plan. The principal conceptual differences include:

- The decision to develop the precision DME in the L-Band as the primary choice (while still retaining the C-Band in the signal format as a backup). This could make the DME systems used for CTOL approach and landing guidance fully interoperable with standard enroute navigation DME.
- The option to use marker beacons for range determination at small community airports having a limited performance MLS, where DME services are not required.
- The decision to develop the flare element in the C-Band (rather than the Ku-Band) to have all angle guidance subsystems operate on the same frequency. The radar altimeter is also an option to achieve the flare capability where it is operationally suitable.
- The agreement by the Military Services to test a tactical MLS during MLS Phase III with angle systems operating in the C-Band. However, the Ku-Band MLS signal format and frequency allocation will remain available for potential future military use.
- The selection of Time Reference Scanning Beam as the preferred technique which offers the best balance of high performance and low costs.
- The decision to permit the use of conical reference geometry as a means of allowing the use of a simpler antenna design.
- The decision to increase the output data rates of the angle guidance signals so as to permit greater information smoothing for improved performance in multipath.

2.0 DEVELOPMENT PLAN

This update of the development plan first describes the changes that have been made in the 1971 plan, and then for both the Industry Development Program and Supporting Government Program activities, it discusses the status of the activity and the remaining tasks for each of the participating agencies.

2.1 Changes to the 1971 Plan

There have been several significant changes to the 1971 development plan:

- Redefinition of System Configurations
- Change in Program Management for Military Systems
- Policy Change for funding Supporting Programs.

The following paragraphs discuss each of these changes and the rationale for the change.

2.1.1 Configuration Change

The original National Plan listed seven MLS configurations. These were based on the configurations defined by RTCA, SC-117, and each was designed to have a specific performance level to meet the needs of specific civil and military users.

During the assessment process at the conclusion of Phase II, the aviation user groups recommended redefining the MLS configurations. This resulted in reducing the number of individual ground systems needed for test and evaluation during the development program from the orginal seven to six. This reduction was made with the full assurance that the capability to meet the requirements of all user groups will be tested during Phase III. The various system configurations as now defined are for convenience purposes in terms of describing different performance levels for the systems. In accordance with the overall modularity concept of the MLS design, any civil system can be built up using the right combination of sub-system elements necessary to

provide the desired performance capability at a particular site at the lowest possible cost.

A typical system configuration consists of an Approach Azimuth Subsystem, an Elevation Subsystem, and a Distance Measuring Equipment (DME) Subsystem. A Flare Subsystem and/or a Missed Approach Subsystem may be included as required by the service to be provided at an individual site. In the case of the Approach Azimuth and Elevation Subsystems, several antenna beamwidths are to be made available to meet the angle accuracy requirements of individual users or sites. The list below gives the present names and brief descriptions of the six ground configurations whose performance capabilities are further detailed in table 2-1.

2.1.1.1 Basic System

The Basic System is intended to fulfill all civil (and selected military fixed-base) Cat I and Cat II needs. It is low in cost and simple to install and maintain. The specifications define several azimuth and elevation antenna beamwidths (antenna apertures) to meet the broad range of airport requirements. A Basic (Wide) system derives its name from its use of a wide aperture antenna which provides narrow beam widths together with high accuracy. A Basic (Narrow) system has a narrow aperture antenna which provides broad beam widths and lower accuracy. In practice the selection of the particular antenna (wide or narrow aperture) depends on the siting requirements of the individual runway.

2.1.1.2 Expanded System

The Expanded System is intended to fulfill the needs of all users of the full capability Category III system for both civil and military fixed base applications. While certain modules of the Expanded System will be technically equivalent to those used for the Basic (Wide) System, there are several fundamental differences. The Expanded System will normally have the complete set of subsystems needed for Category III, including Flare and Missed Approach

Table 2-1. Performance Capabilities of MLS Configurations

SUB-SYSTEM \ CONFIGURATION	COVERAGE/ACCURACY (2σ) SEE NOTE 3						
	EXPANDED	BASIC		SMALL COMMUNITY	SHIPBOARD	JOINT TACTICAL	AIR TRANSPORTABLE CAT II/III
		WIDE APERTURE	NARROW APERTURE				
AZIMUTH	±40° Prop. Guid. PF:0.05° CM:0.04°	±40° Prop. Guid. PF:0.05° CM:0.04°	±40° Prop. Guid. PF:0.10° CM:0.08°	±10° Prop.Guid. ±40° Sector Guid. (See Note 1) PF:0.33° CM:0.10°	±40° Prop. Guid. PF:TBD CM:TBD	±40° Prop. Guid. PF:TBD CM:TBD	±40° Prop. Guid. PF:0.05° CM:0.04°
ELEVATION	0° to 20° Prop. Guid. PF:0.1° CM:0.05°	0° to 20° Prop. Guid. PF:0.1° CM:0.05°	0° to 10° Prop. Guid. PF:0.1° CM:0.05°	1° to 10° Prop. Guid. PF:0.16° CM:0.10°	-10° to 20° (See Note 2) PF:TBD CM:TBD (See Note 5)	1° to 20° Prop. Guid. PF:TBD CM:TBD	0° to 20° Prop. Guid. PF:0.1° CM:0.05°
FLARE	8 Ft above Runway to 8.5° Prop. Guid. PF:0.034° CM:0.02°	N/A	N/A	N/A	N/A	N/A	8 ft. above Runway to 8.5° Prop. Guid. PF:0.034° CM:0.02°
MISSED APPROACH AZIMUTH	±40° Prop. Guid. PF:0.1°	N/A	N/A	N/A	N/A	N/A	±40° Prop. Guid. PF:0.1°
DME	±40° 100 ft.	±40° 100 ft.	±40° 100 ft.	±40° (See Note 4)	±40° 20 ft.	±40° 360° Opt. 20 ft.	±40° 20 ft.

NOTES:
1. SECTOR GUIDANCE PROVIDES DIRECTIONAL GUIDANCE ONLY (FLY LEFT, FLY RIGHT, OR FLY UP, FLY DOWN)
2. LOOK DOWN ELEVATION GUIDANCE REQUIRED DUE TO SITING CONDITIONS: PROPORTIONAL GUIDANCE THROUGHOUT RANGE.
3. PF = PATH FOLLOWING/ACCURACY, CM = CONTROL MOTION NOISE ACCURACY, (BOTH WITH REGARD TO MINIMUM DECISION HEIGHT)
4. CIVIL/MILITARY USE: DME. CIVIL USE: MARKER BEACONS OR DME.
5. TBD = TO BE DETERMINED.

elements. In addition, it must incorporate special monitoring and the redundant components needed for high reliability and integrity during the critical flare maneuver in Category III operations.

2.1.1.3 Small Community System

During the technique selection process the need for, and the importance of, low cost systems for general aviation use in small community airports was identified and strongly supported by the MLS Advisory Committee. In essence, this is a "design to cost" system in which the basis for design was an assumption as to the expenditure that could be justified at small community airports and by small aircraft operators. Thus the Small Community system provides the minimum level of service.

2.1.1.4 Tactical System (Man-Transportable)

The unique requirements of the military for tactical operations require the MLS to perform satisfactorily in unimproved tactical landing areas. These areas may include buildings and revetments in close proximity to the landing area, and other aircraft maneuvering on the ground and in the air near the ground equipment. The Tactical System also has severe size and weight constraints which prohibit utilizing larger equipment sizes used in civil systems to provide equivalent capabilities. In spite of all the above limitations, the Tactical System is required to provide CAT II guidance accuracy for military fixed and rotary wing aircraft.

The Tactical System will consist of small, lightweight, transportable ground equipment which can be operated in either a split site (i.e., Azimuth and Elevation Subsystems separately located) or a collocated configuration, and associated airborne equipment which can operate in both fixed and rotary wing aircraft.

A single Tactical System design will be tested by the three military services to determine its ability to satisfy their requirements.

2.1.1.5 Shipboard System

This is the configuration planned to compensate for ship motion and to provide other special features needed for Category III automatic landing operations aboard aircraft carriers. Prototype development and testing of this configuration by the Navy is essential in Phase III to verify the suitability of the MLS as a replacement for the current Automatic Carrier Landing System (ACLS). The capability to operate under realistic shipboard operating conditions will be examined closely.

2.1.1.6 Air Transportable Military Cat II/III System

This system is required for USAF Forward Operating Base and USMC Expeditionary Field Operations worldwide. This configuration will be capable of being set-up within 24 hours on an austere runway, with minimum civil engineering and maintenance support, and provide flight certified Category II/III service. However, since this system would employ the same technological base and signal format as the civil Expanded System, it was not considered to be an additional prototype to be funded by FAA, but rather would be funded by the military services as a follow-on activity to demonstrate the feasibility of satisfying its unique packaging and portability requirements.

2.1.1.7 System Performance Capabilities

A summary of the system performance capabilities of the various configurations is shown in table 2-1.

2.1.2 Change in Program Management for Military Systems

The original National Plan outlined a very comprehensive plan for management of the MLS development program. It recommended the establishment of a Program Management Office in the Systems Research and Development Service in FAA to provide overall program management and direction to the program. In addition to having the responsibility for coordinating the concurrent supporting

activities of each of the participating agencies, the FAA was assigned the responsibility for managing the Industry Development Program.

This plan was followed precisely throughout Phases I and II of the program and also throughout the Phase III activity covering development, test, and evaluation of the Small Community and Basic (Narrow) Systems. It is also planned to continue this plan for the development of the remaining civil system configurations to be developed.

However, it is felt that the military services are much better equipped to carry out the unique coordination and contracting aspects required for the military systems development and it is proposed to assign program management responsibility for these systems to DOD as described in Section 2.5. The FAA will maintain overall responsibility and control over standardization and signal format architecture.

2.1.3 Policy Change For Funding Supporting Government Programs

The Supporting Government Programs part of the original plan was comprised of a very comprehensive list of specific supporting tasks to be accomplished by and funded by each of the participating agencies.

In 1972, the Subcommittee on Defense of the House Appropriations Committee, in denying an Air Force request for MLS support funds, stated: "The Committee does not feel that there is a requirement at this time for Air Force funding. When the system is substantially completed, the Air Force can, at that time, study those needs related to Air Force requirements. Until then the effort should be funded by the FAA."

This language was interpreted to mean that the FAA should assume budgeting/financial responsibility for the development of both military and civil prototype configurations of MLS, and that DOD would be responsible for funding the testing and evaluation of the prototypes developed by the FAA for military use.

As a result of this ruling, each of the uncompleted supporting tasks, previously planned to be funded by one of the Military Services, was reassessed for its importance to the MLS program at that time. Some tasks no longer considered essential to the success of the program were deleted or curtailed.

Those tasks still considered essential were incorporated into the FAA funded support program and the results made available to the participating agencies and the systems development contractors.

2.2. Industry Development Program

2.2.1 Background

The program tasks contained in the July 1971 National Plan were:

- Task A - Request for Proposal (RFP) - Completed
- Task B - Evaluation of Proposals - Completed
- Task C - Technique Analysis and Contract Definition - Completed
- Task D - Government Evaluation - Completed
- Task E - Feasibility Model Demonstration - Completed
- Task F - Development of Prototypes - Initiated
- Task G - Flight Test and Evaluation of Prototypes - Initiated
- Task H - Design Decisions and Production Specification - Initiated

Tasks A thru E (Phases I and II) were conducted essentially as defined and were completed in December 1974. This was approximately eleven (11) months behind the original schedule established in 1971. Much of this slippage was deliberate. In order to assure that appropriate decisions were made before progressing to succeeding major phases of the program, the government evaluations between phases were made much more comprehensive and thorough than originally planned. The Technique Selection Process at the end of Phase II lasted six months (rather than two as scheduled) and involved more than 100 technical experts from Government and Industry, national and international.

Phase III is comprised of Tasks F, G, and H, and was initiated in July 1975.

2.2.2 Phase III Development Work That Has Been Completed

The original plan envisioned the awarding of contracts for the development of prototypes for all of the system configurations at one time. The plan specified that five ground systems were to be awarded to one contractor and

four were to be awarded to the other contractor, together with a specified number of airborne sets. However, in light of the pending ICAO competition, and heeding the advice of the MLS Advisory Committee, the decision was made to utilize the available FY76 funds to develop only two of the MLS configurations at that time and defer development of the other configurations until after the ICAO decision. Accordingly, the Phase III development activity was initiated in July 1975 with the award of competitive contracts for the development of two prototype systems (one Small Community System and one Basic (Narrow) System) from each of the two Scanning Beam development contractors, the Bendix Corporation and Texas Instruments, Inc.

The Bendix Corporation made satisfactory progress on both the ground and airborne sub-system developments and made deliveries essentially on schedule. Texas Instruments made reasonable progress on the ground sub-system developments but not on the airborne sub-system, which had been sub-contracted to another firm. After approximately seven months, it was determined that the rate of progress was not satisfactory and costs appeared to be excessive; therefore, the airborne sub-system development with Texas Instruments was terminated. Subsequently, a contract was awarded to the Bendix Corporation for ten additional airborne sub-systems (including precision L Band DME interrogators) for use with the Basic (Narrow) Systems, for the military services.

All of this prototype hardware has now been delivered and has undergone extensive test and evaluation by FAA, NASA, and the military services. The contractors have submitted draft production specifications for proposed production equipment. This completed the prototype development program for the Small Community and Basic (Narrow) configurations.

2.2.3 Phase III Work to be Accomplished

The decision was made to defer all remaining Phase III program activities pending the ICAO selection of a MLS for international standardization. The ICAO selection has now been made. At the All Weather Operations Divisional Meeting held in Montreal, in April 1978, the U.S./Australian TRSB system was selected as the future standard system for international civil aviation. The

remaining Phase III activities still to be accomplished are the prototype development, test and evaluation of the Basic (Wide) and Expanded civil systems, and each of the military systems as discussed below.

2.2.3.1 Expanded and Basic (Wide) Systems

The procurement approach to be used in the development of the Basic (Wide) and Expanded Systems is to first develop the Azimuth, Elevation and precision L-Band DME subsystems which make up the Basic (Wide) system. This is planned to be done in a cooperative venture between FAA and NASA in order to provide a precision approach and landing guidance system for use in conjunction with the NASA Terminal Configured Vehicle (TCV) program. NASA transferred $600,000 to the FAA, and FAA is providing the additional funds required to develop these subsystems. The Elevation Subsystem will utilize the "COMPACT" circuit technique. This Basic (Wide) system will be installed at the NASA Wallops Flight Center, Wallops Island, Virginia, where it will be tested jointly by NASA, FAA, and the military services. NASA is providing additional funds for procurement of three MLS receivers and two test sets for use with this system in the TCV program.

In FY-79 and FY-80, the FAA is programming funds to fabricate a Flare Subsystem and a Missed Approach Azimuth Subsystem to incrementally upgrade the Basic (Wide) System and to demonstrate the technical capabilities of an Expanded System. While this will not include all of the monitoring and redundancy of a full Expanded System for Cat III operations, the guidance signals provided will be equivalent to that of a full system. Evaluation of these subsystem components will provide data for producing draft specifications for the Technical Data Package to be delivered to the Airway Facilities Service of FAA.

2.2.3.2 Joint Tactical Microwave Landing System (JTMLS)

The Joint Tactical Microwave Landing System (JTMLS) development will capitalize upon the collective background and technology base already estab-

lished. A contract is planned for award by the Army for the design and fabrication of Advanced Development (AD) models of the JTMLS. This contract will be administered by the JTMLS Lead Service Program Office at Ft. Monmouth, N.J. The objective of this effort is to develop a landing system which will provide rotary and fixed wing aircraft with the capability of making safe instrument approaches to and landing on minimally prepared tactical sites under adverse weather conditions. An effort will be made to design the highest feasible accuracy into the JTMLS system when using a C-Band angle subsystem and a precision L-Band DME. During the AD phase, it is planned to resolve any remaining technical questions, such as the capability of the L-Band DME to provide the improved accuracy required for certain military applications and the ability to package C-Band, ground angle guidance equipment for tactical use. In addition, design-to-cost objectives will be imposed to develop equipment that is affordable for the Military Services. The JTMLS AD models will be tested and evaluated to confirm that the MLS angle guidance and the precision L-Band DME sub-systems designed to meet military specifications can satisfy military operational requirements. Currently, the FAA has $6.5M in FY-78/79 budgeted for this contract effort.

2.2.3.3 Shipboard Systems

Advanced Development of a prototype Shipboard System, including associated airborne components is planned to be initiated in FY-80 as part of the FAA funded Phase III effort. The Navy will be designated as the Lead Service for development of this system configuration in coordination with other MLS developments being pursued in parallel. The system development will be administered by the Navy MLS Program Office of the Naval Air Systems Command. The objective of this effort is to provide a configuration suitable for installation aboard an aircraft carrier for technical flight test and evaluation to determine suitability of the TRSB MLS concept and signal format to satisfy the unique requirements for carrier-based landing operations. Primarily, this prototype development will extend the previously developed MLS technology base for adaptation to the unique shipboard installation and operation requirements

particularly in design areas such as:

- Antenna design for physical location on the ship's superstructure to withstand the rigors of shipboard vibration and the external salt air environment.
- Electronically minimizing the effects of multipath reflections from the sea surface, the flight deck and aircraft parked on the aft portion of the flight deck.
- Stabilization of the MLS antenna to remove the effects of the ship's motion.
- Generation and transmission of ship's motion data to the airborne equipment for use in the air-derived computations necessary for landing on a moving flight deck.
- Design of airborne signal processors to provide suitable data outputs for use with existing aircraft autopilots and flight control systems.

2.2.3.4 Air Transportable Category II/III System

The procurement of this configuration is planned to be initiated by and funded by DOD in Fiscal Year 1980. The techniques established during the Basic Wide and Expanded system developments will provide the baseline.

2.2.4 Phase III Development Schedule

The schedule for Phase III development is as shown in table 2-2. A graphic presentation of the complete industry development program schedule is shown in figure 1-1, page 1-5.

2.3 Supporting Government Programs

2.3.1 Background

Supporting Government Programs, interrelated to and interdependent of the "mainstream" System Development Program, have been and will be conducted concurrently by the individual participating Government agencies, either in-house or with separate contract support. The Supporting Government Programs include

Table 2-2. Phase III Development Schedule

SYSTEM	CONTRACT AWARD	EQUIPMENT DELIVERY COMPLETE	TEST AND EVALUATION COMPLETE
Basic Configuration	July 1975	January 1977	April 1978
Small Community Configuration	July 1975	January 1977	April 1978
Basic (Wide) Configuration	July 1978	June 1979	July 1980
Upgraded to Expanded	FY 79-80	December 1980	July 1981
Joint Tactical* Configuration	May 1979	TBD**	TBD**
Shipboard* Configuration	TBD**	TBD**	TBD**
Air Transportable*	TBD**	TBD**	TBD**

*DOD managed
**To be determined

three areas of effort:

(1) Technique Investigations;

(2) Application to User Needs; and

(3) Flight Test and Evaluation.

In each of these areas, specific task assignments have been undertaken by the Army, Navy, Air Force, NASA, and FAA.

2.3.2 Technique Investigations

This effort included analyses, tests, and experiments directed at establishing knowledge and a data base in the Government to better prepare it to conduct comprehensive technical evaluations of industry proposals and subsequent analytical and experimental efforts. This work not only assisted in the selection of the system technique and signal format in February 1975, but also supported the required technical validation of the selected technique. Early investigations using existing Doppler and Scanning Beam R&D hardware have addressed issues such as required data rate, low angle ground effects, C-Band and Ku-Band propagation (including multipath effects), and effects of siting geometry upon airborne signal processing requirements. Other investigations involved encoding and decoding techniques, modulation techniques, the planar versus conical antenna design question, and problems associated with a two-frequency-band system.

Several new design techniques or technological developments having potential for improving performance, or reducing component costs have also been investigated. Examples of these efforts are two antenna subsystem developments which have been used in Small Community systems; one was developed by the Hazeltine Corporation under a Naval Research Laboratory (NRL) contract, and the other by Meyer Associates under a Transportation Systems Center (TSC) contract. The Hazeltine development is the "COMPACT" antenna concept which has demonstrated the capability to provide low cost phased array antennas without sacrificing performance. After satisfactorily completing initial tests at NAFEC, the Hazeltine Small Community system was used in Montreal, for flight demonstrations for delegates attending the AWO Divisional meeting of ICAO in April 1978. The Meyer Associates development was designed to investigate all-solid-state C-Band transmitters and an alternative low cost antenna design.

Acceptance tests of this system are scheduled to be completed at NAFEC by August 1978.

2.3.3 Application to User Needs

Included in this area of effort were those activities required to assure effective utilization of the airborne receiver's output. This was done to verify that the selected system technique would satisfy the spectrum of established operational requirements (OR's). These activities provided the technology data base required for the development and evaluation of flight control and display techniques, and determined the performance requirements for signal processors.

Other studies have been conducted to assure suitability of proposed and selected techniques to meet certain unique military requirements and to make the system more cost effective. For instance, military requirements for certain applications specify a precision DME system having accuracies of 20 feet (2 sigma) in range and 2 feet per second in range rate. Present FAA plans for civil systems call for an L-Band DME which provides an accuracy of 100 feet (2 sigma) in range. Support contractors are investigating the design charateristics of a more precise DME to be used when greater accuracies are required.

2.3.4 Flight Test and Evaluation

Included in this area of effort are those activities required to confirm the potential of the TRSB MLS concept and signal format to satisfy both civil and military operational requirements; to provide actual flight test data to ICAO; and to evaluate contractor compliance with Phase III prototype equipment specifications.

2.3.4.1 FAA Test and Evaluation

The principal flight tests were conducted at the FAA's National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, and NASA's

test site at the Navy Auxiliary Landing Field (NALF), Crows Landing, California. The Bendix Phase II equipment located at NAFEC was modified in early 1975 to incorporate the signal format resulting from the 1974 technique assessment and was utilized subsequently as a test bed to collect data for the U.S. submission to ICAO and to demonstrate the coverage and accuracy of a full capability TRSB MLS. Other MLS systems that were installed and tested at NAFEC were: Bendix Basic (Narrow), Bendix Small Community, Texas Instruments Small Community, plus the two alternative low-cost designs for a Small Community System - one developed by Meyer Associates, and the other by the Hazeltine Corporation.

The Texas Instruments Basic (Narrow) system was installed at Crows Landing, California, in early 1977, and has been utilized for test and evaluation by NASA, the FAA, the U.S. Navy, and the U.S. Air Force. Approximately 700 formal test runs have been flown at NAFEC, requiring over 200 flying hours in four different FAA aircraft types, with supporting flights by special Army, Navy, and Air Force aircraft. This was in addition to the preparatory flight testing and the static ground testing for each MLS system discussed above.

2.3.4.2 U.S. Air Force Test and Evaluation

The U.S. Air Force has been conducting a program since 1975, called "Flight Profile Investigation (FPI) for MLS." The program has a two-fold objective, i.e.:

(1) to determine which flight profiles are feasible with MLS when flown by aircraft having various capability levels of flight controls and displays, and;

(2) to establish a baseline for determining the aircraft controls and displays needed to fully exploit the capabilities of the MLS.

The first of these objectives has been completed. A T-39 (Saberliner) aircraft, which has flying characteristics that are representative of executive-type twin jet aircraft was utilized to conduct more than 650 TRSB MLS approaches. As a part of the Flight Profile Investigation Program, the USAF accomplished manual and coupled TRSB MLS curved and segmented approaches and automatic landings at NAFEC and other national and international MLS demonstra-

tion sites in support of the ICAO submission.

2.3.4.3 U.S. Army Test and Evaluation

During June-August 1977, the U.S. Army Avionics R&D Activity conducted flight tests on the civil Basic Narrow MLS configuration located at NAFEC. An Army UH-1B helicopter equipped with conventional displays, flight director, and autopilot flew approximately 70 approaches. Unique helicopter flight profiles (decelerated approaches and steep angle approaches) were investigated and data was collected for analysis.

2.3.4.4 U.S. Navy Test and Evaluation

During 1977, the U.S. Navy evaluated an airborne MLS subsystem installed in a carrier type F-4J aircraft. Seventeen manual and automatic approaches were flown on the MLS test site at NAFEC while 126 manual and automatic approaches were flown at the Navy Auxiliary Landing Field (NALF) Crows Landing MLS test site.

Tests with the F-4J aircraft, which is representative of Navy/Air Force high performance tactical aircraft, demonstrated:

- The feasibility of installing production type MLS equipment in a Navy tactical aircraft which does not degrade the existing capability of the SPN-42 Automatic Carrier Landing System (ACLS) and the SPN-41 Shipboard Instrument Landing System.
- The capability of a present-day production/fleet autopilot to utilize the MLS.
- The capability of TRSB to satisfy the unique aircraft performance requirements within the context of closed loop path control during automatic approaches on Navy carriers.

Additionally, data was collected to determine the noise content of the MLS beam and its affect on aircraft control surface deflections and critical structural loads. Accuracy data on the NALF Crows Landing MLS test site obtained during Navy test flights was provided to the FAA for use in support of the U.S. submission to ICAO.

2.3.4.5 NASA Test and Evaluation

For the past four years, NASA Ames has conducted flights in STOL aircraft equipped with advanced digital avionic and display systems to evaluate displays, control systems, and terminal area procedures using various degrees of automation and manual flight. Much of the work in prior years was done utilizing the MODILS, an early time reference type of scanning beam microwave landing system implemented at C-Band. A Basic Narrow TRSB MLS system was installed at NALF Crows Landing, California, in early 1977. Comprehensive static and dynamic tests have been performed to validate the prototype MLS for STOL applications. The flight validation tests were conducted with STOL aircraft such as a Twin Otter and a modified C-8A Buffalo, and are planned for the Quiet STOL Research Aircraft, all equipped with advanced digital avionics equipment. A piloted simulation was used concurrently with the flight validation program to increase the productive time of the flight test program and to provide data supplementing and extending the flight test results. The test program consisted of manual and coupled automatic approaches in STOL aircraft to evaluate the adequacy of the TRSB MLS signals for STOL approaches and landings.

In a cooperative effort with FAA, NASA has conducted investigations to develop a feasibility model of a low cost airborne MLS receiver for general aviation use. A design has been achieved and is ready for flight evaluation. Flight validation of the receiver will be conducted at NALF Crows Landing, using the installed MLS ground equipment.

NASA's Terminal Configured Vehicle program includes the conduct of analytical, simulation, and flight test research which will support improvements in (1) terminal area capacity and efficiency, (2) approach and landing capability in adverse weather, and (3) operational procedures to reduce air-craft noise impact on the ground. In pursuing these objectives, NASA participated with the FAA in the demonstration of TRSB MLS performance capabilities. During these demonstrations (NAFEC, Buenos Aires, New York, and Montreal), TRSB MLS was utilized to provide the TCV Boeing 737 research aircraft (representative of an air carrier jet aircraft) with guidance for automatic control during transition from conventional RNAV to MLS guidance in curved, descending flight

profiles, flare, touchdown, and rollout. This aircraft has accomplished more than 400 landings using TRSB MLS for approach and landing guidance.

2.3.4.6 International Demonstrations

In the fall of 1977, the ICAO Council requested that States proposing systems as candidates for international standardization demonstrate the capability of their systems in actual operational environments. This was an attempt to obtain as much information as possible on the proposed landing systems, so that an informed decision to standardize on one system could be made.

TRSB demonstrations were conducted during the period October 1977 thru April 1978. The list of sites is shown below in the order in which the demonstrations were made. Those indicated by an asterisk (*) were sites where the Doppler system was also demonstrated in accordance with an independent bilateral agreement between the U.S./FAA and the U.K./CAA to obtain comparative data on the TRSB and Doppler systems.

(1) Cape May, New Jersey
(2) Buenos Aires, Argentina
(3) Tegucigalpa, Honduras
(4) JFK Airport, New York*
(5) Kristiansand, Norway*
(6) Brussels, Belgium*
(7) Charleroi, Belgium
(8) Dakar, Senegal
(9) Nairobi, Kenya
(10) Shiraz, Iran
(11) Montreal (Dorval International), Canada
(12) Montreal (Victoria STOL Port), Canada

A report covering each of the demonstrations (except Montreal) was made available to ICAO. This program was very effective in demonstrating the excellent performance, reliability, and ease of set-up of the equipment. All demonstrations were conducted as scheduled and there was not a single instance of an aborted approach.

2.3.5 Future Supporting Government Programs

Some tasks still need to be accomplished before the development program can be considered completed. The major task for each of the participating agencies, as stated in the original plan, is to conduct flight tests to determine that the MLS design is completely suitable and adaptable to its needs. In addition, there is a continuing need for supporting investigations for unique user requirements and state-of-the-art improvements. Listed below are the principal tasks planned:

- Prepare and coordinate Standards and Recommended Practices (SARPS) for MLS
- Perform supplementary development tasks needed to prepare for the transition from system development to system implementation.
- Determine suitability of L-Band DME to meet overall requirements for the full scope of MLS applications.
- Test and evaluate military configurations and civil Category III configurations.
- Continue the analyses, tests, and evaluations leading to airborne system integration.
- Evaluate subsystem and component improvements
- Investigate MLS growth capabilities
- Continue and complete the Air Force investigations on "MLS Application to User Needs".

2.3.5.1 Prepare and Coordinate Standards and Recommended Practices (SARPS) For MLS

At the same ICAO meeting, in April 1978, in which the TRSB system was selected for international standardization, planning was initiated for the next major milestone to be accomplished. That milestone is the preparation of Standards and Recommended Practices (SARPS) for ICAO Annex 10, "Aeronautical Telecommunications". As the developer (with Australia) of TRSB, the U.S. will be involved in the preparation and coordination of the SARPS for the MLS. In essence, the SARPS prescribe the technical and operational characteristics of

the system in order that the quality of system performance is maintained and to ensure that there is interoperability between aircraft avionics and the MLS ground facilities throughout the world.

Another document, to be prepared concurrently with the preparation of SARPS, is a "MLS Handbook", which will include an overall system description and will record the decisions and rationale adopted during the ICAO process to prepare SARPS. This will replace the present Functional Requirements Specification. In the interim, the MLS Signal Format Specification will be updated to permit continuing development in the U.S.

2.3.5.2 Perform Supplementary Development Tasks Needed to Prepare For the Transition From System Development to System Implementation

A major activity during the transition phase between system development and system implementation would be a Service Test and Evaluation Program(STEP). The objectives of this program are to develop and evaluate operational procedures and commissioning procedures, and to demonstrate the capabilities of MLS to aviation user groups. The Service Test and Evaluation Program would be managed by the FAA Operating Services and the systems deployed are expected to eventually become the initial MLS operational facilities.

From a development viewpoint, there are also a number of tasks that will be performed during the transition period. The principal areas of effort will be to develop:

- Criteria and techniques to locate the optimum site for any installation
- Techniques (including flight inspection) to validate and commission MLS facilities
- Specifications for the collocation of ILS and MLS
- Reliability and maintainability concepts
- Standards for the integration of MLS into the NAS.

2.3.5.3 L-Band DME

The precision L-Band DME developed as a part of the Phase III Basic (Narrow) configuration has an accuracy requirement of ±100 feet (two sigma)

and should satisfy currently known civil CTOL landing system requirements. (Preliminary test data indicates actual performance is considerably better than this, but additional testing and evaluation is still required.) This DME, however, will not satisfy the ±20 feet (two sigma) accuracy required for certain military operations. During extensive coordination between the FAA and DOD during 1977-1978, a signal format specification for a more precise L-Band DME has been developed. Development and testing of this DME will be undertaken as a part of the JTMLS program to determine its suitability for military applications. The availability of 200 L-Band DME channels and the feasibility of hard-pairing them with the 200 angle channels still needs to be thoroughly examined.

2.3.5.4 Test and Evaluation of Additional MLS Configurations

Additional MLS configurations are scheduled for prototype development as discussed in Section 2.2.3: the Basic(Wide)/Expanded Civil Category III configuration, the military Joint Tactical configuration, the Shipboard System, and the Air Transporable System. The testing and the evaluation of these configurations by all of the participating agencies is the principal remaining task to be accomplished as a "Supporting Government Program." The Basic (Wide)/Expanded Category III system will be evaluated by DOT, DOD, and NASA; the Tactical System will be evaluated by all of the Military Services; the Shipboard System by the U.S. Navy; and the Air Transportable System by the Air Force and the Navy. The Basic Narrow and Small Community systems, previously developed and tested, are currently scheduled to remain at NAFEC and Crows Landing during 1978-1980, so as to be continually available for test and/or demonstration to the aviation community. If required, certain of these equipments may be transported and installed at other appropriate sites to support the development of operational and maintenance concepts or to facilitate international understanding of MLS.

2.3.5.5 Continue the Analyses, Tests, and Evaluations Leading to Airborne System Integration.

The MLS has hardware, software or procedural interfaces with a number of other aircraft subsystems. Continued study and evaluation of these interfaces is needed to be certain that the MLS operates compatibly in the airborne environment.

One important interface is with the displays that pilots will use to fly the MLS. Past work has emphasized the use of MLS with existing displays to keep costs at a minimum. In the future, the emphasis will change to new displays such as those that enable pilots to take full advantage of the volumetric coverage of MLS in flying multiple paths and curved approaches. Another area where new displays may have a large role is in the critical flare maneuver where advanced concepts such as head-up-displays will be explored.

The interface with Automatic Flight Control Systems (AFCS) is important because the trend in large aircraft (such as the airlines and military aircraft) is to rely increasingly on automatic flight during approach and landing. The MLS signal format was designed to have data rates and noise characteristics that are well suited for this type of operation. However, further flight testing (and simulation) is required to ensure compatibility of this interface.

After a landing approach is made using the MLS elevation guidance signal, there may be a changeover to flare guidance using the MLS Flare Subsystem or to the radio altimeter--or the aircraft may need to use the Missed Approach Subsystem. The objective of this task is to determine the optimum techniques and designs to make this changeover smooth and harmonious.

Because of the directivity of some airborne MLS antennas and the blanking of signals by the aircraft fuselage and wings, there will be many applications where multiple antennas are needed. This in turn presents the problem of where antennas should be located and when and how antenna switching should be accomplished.

2.3.5.6 Evaluate Subsystem and Component Improvements

A number of subsystem and component improvements are planned during 1978-1980. In general these efforts are directed at extending and taking advantage of technology that has proven useful in the development efforts to date. These are low risk tasks, yet they will result in the fulfillment of important MLS capabilities.

Antenna investigations will be continued which have the objectives of improving performance or reliability and reducing costs.

Some of the work areas will be: monitoring, cost reduction, frangibility, frequency sensitivity, and spectrum considerations.

Component investigations will also be continued which have the objective of applying the latest technology to the MLS design. Application of state-of-the-art solid state technology, in particular, is expected to make improvements in such items as phase shifters, RF power sources, and low cost receiver components.

2.3.5.7 Investigate MLS Growth Capabilities

In the course of several reviews of the MLS operational requirements, the question of 360° coverage for azimuth and ranging guidance has been raised as a potentially useful added capability. This concept was reinforced during the AWOD meeting of April 1978, at which it was agreed that the development of a 360° azimuth element for TRSB and the exploration of such an element integrated with the L-Band DME should be encouraged. The TRSB signal format has provisions for such coverage.

Another growth capability that warrants investigation is the siting of azimuth antenna elements on each side of the approach runway so that no equipment is needed on the extended centerline of the runway (i.e., splitting the azimuth antenna). This would significantly reduce the hazard to aircraft which are flying below the obstruction clearance plane or overrun the runway end during emergencies on the take-off or on a missed approach.

Still another growth feature that might be useful at difficult runway sites would be the siting of the azimuth antenna to the side of the runway

centerline. This would require the investigation of both technical factors and operational flight procedures.

2.3.5.8 MLS Application to User Needs

FAA-USAF Interagency Agreement DOT-FA74WAI-416, under which the Air Force is conducting a series of MLS flight control investigations of mutual civil-military user interest, is still in effect. Two T-39 USAF aircraft have been extensively modified to provide a wide range of flight control and display options as needed to realistically exercise and evaluate the full capabilities of each civil and military MLS prototype ground and airborne configurations as it is developed. An equally or more important objective is to determine, from lessons learned in the T-39 MLS flight test program, the types and levels of information, displays, and controls pilots need to take advantage of the full capabilities of the new MLS to fly curved and segmented paths manually, or for monitoring the safety and precision of automatic MLS approaches and landings.

Concurrently with the T-39 flight test program, an associated Air Force MLS program support effort is proceeding to develop and validate design criteria for improved or new aircraft control/display configurations capable of executing, totally on instruments, complex flight paths using MLS in conjunction with other navigation sensors. One program objective is to establish an optimum balance between manual and automatic control-displays as applicable to different types of aircraft and differing MLS flight profiles. Another objective is to feed-back detected MLS sensor interface problems or weaknesses into the mainstream MLS development programs.

2.3.6 Related Programs

In addition to those efforts that are essential to the development or utilization of the MLS, the FAA, DOD, and NASA, have all been conducting programs that have an effect on, or are related to, the MLS. In general, these are related avionics programs or projects in which there will eventually be a hardware or software interface with the MLS. Since this type of activity would be required regardless of whether or not there was an MLS development

program, the cost of these efforts are not considered a direct charge to the MLS program. Examples of such related programs are discussed below:

2.3.6.1 NASA Airborne Systems Technology Investigations

It has been demonstrated that in automatic and manual flight, the volumetric signal coverage of the TRSB MLS can be exploited to enable commercial air carrier class airplanes, light wing loading STOL aircraft, and powered-lift STOL aircraft to perform new precision operational maneuvers. These include curved and descending paths with precision turns to short final approaches terminating in landing and rollout even when subjected to turbulence, variable tail-wind and cross-wind components, and wind shear. The avionic techniques used in demonstrations for the processing and display of the TRSB MLS signals are illustrative of the application to future system design. However, additional investigations are needed to simplify and bring to a more advanced state of readiness, the onboard avionics and flight control procedures which exploit the utilization of MLS. Investigations that will be conducted by NASA at Wallops Flight Center, NAFEC, and NALF Crows Landing, will include the following:

- RNAV/MLS Transition. This addresses the need to configure the control laws, avionics, and crew operating procedures to validate MLS acquisition and minimize abrupt aircraft maneuvers caused by differences in expected position during navigation, and by the transition from RNAV to MLS systems.
- MLS Flight Path Characterization. This effort will identify, from optimized curved paths, the maneuvers to be performed in the MLS coverage volume and will translate this knowledge into generalized control laws for acquiring the runway by automatic or manual means from arbitrary initial paths and positions within the terminal area. The potential advantages to be gained from widened MLS azimuth coverage will be examined.
- Runway Productivity Improvement. This effort will identify, through combined use of MLS and highspeed runway exits, the appropriate sensors, control laws, displays and crew procedures needed to reduce

runway occupancy time. This effort will yield measurements from which to determine reasonable lower limits in runway occupancy time, touchdown dispersion, aircraft braking schedule, ground handling characteristics, tire wear, and turnoff geometry effects. Successful implementation of these tests requires both MLS and precision flare laws to minimize touchdown dispersion.

- Cockpit display of flight situations adequate for monitoring advanced profiles and traffic situations and for pilot intercedance in contingencies.
- Improved automatic flight control in windshear.
- Flight deck improvement for more efficient utilization of crew and reduction of human errors.
- Time controlled arrivals and flow sequencing.

2.3.6.2 FAA Related Programs

The most critical hardware and software interfaces between MLS and its related programs and projects occur in the airborne portion of the system. As indicated in the paragraphs above, the Air Force and NASA have undertaken the development of a number of such related avionics projects. To supplement that work, the FAA has planned the investigation and evaluation of selected advanced instrumentation concepts such as integrated electronic displays--both head-up displays (HUD) and head-down displays, and wind-shear aiding concepts for both manual and automatic flight control. This will also require investigation of cockpit human factors aspects into the role of the crew and its interaction with the MLS equipment. This will be carried out in coordination with the Air Force and NASA.

2.4 Funding Requirements

2.4.1 General

The current projected funding for each of the participating agencies for the MLS prototype development program is shown in tables 2-3 & 2-4. Prior year figures reflect current approved budgets; future year figures are subject

Table 2-3. FAA Program Funding for MLS
(Millions of dollars)

	FY-75 & PRIOR	FY-76	FY-77	FY-78	FY-79	FY-80	TOTAL
Systems Development							
Phase I	2.9						2.9
Phase II	23.1						23.1
Phase III							
Civil Systems		15.7	2.0	1.4	1.0	1.8	21.9
Military Systems		.5	0	5.5	1.0	*8.0	15.0
Total Systems Develop.	26.0	16.2	2.0	6.9	2.0	9.8	62.9
Supporting Programs							
Supporting Investigations	9.6	1.4	.9	1.4	.9	1.4	15.6
Test & Evaluation	3.6	.9	.7	.7	2.2	.9	9.0
Total Support Programs	13.2	2.3	1.6	2.1	3.1	2.3	21.6
Program Management	1.3	1.1	.9	.9	1.3	1.0	6.5
ICAO Support	4.5	6.1	3.6	3.0	.9	.5	18.6
Total FAA Program	45.0	25.7	8.1	12.9	7.3	13.6	112.6

* In commenting on the DOT Appropriations Bill for 1979, the House Committee on Appropriations approved the transfer of funds to the DOD for 1979 but noted that, "The Committee, however, does not believe that FAA should continue to request funds for DOD's specialized applications. Any subsequent funding for these applications should be requested by the DOD." This comment will be taken into consideration in the preparation of FY 80 budget requests.

Table 2-4. DOD & NASA Program Funding for MLS
(Millions of dollars)

	FY-75 & PRIOR	FY-76	FY-77	FY-78	FY-79	FY-80	TOTAL
DOD Supporting Programs	5.4	2.0	3.8	1.5	8.7	5.8	27.2
NASA Supporting Programs	1.3	1.6	.4	1.1	0	0	4.4

to further review in the regular bugetary process. The FAA funding shown in table 2-3, includes resources required for the Systems Development contract activity performed by Industry, as well as that required for Supporting Programs. All of the DOD and NASA funding shown in table 2-4 was used for Supporting Program activities. (NASA funding includes \$0.6M transferred to FAA for the Basic (Wide) System for use in conjunction with the TCV program).

2.4.2 Future Funding Requirements

The FAA funds identified for civil systems development for FY 78-80 are intended to develop the Basic (Wide) System, together with NASA, and incrementally upgrade this system to the technical capabilities of an Expanded System. It is planned to transfer FAA funds in FY 78-80 to the designated Military Lead Service for prototype development of the Joint Tactical and Shipboard Systems. This will complete the FAA responsibility for funding of civil and military prototype systems development under the Plan.

The military funding for FY 78-80 is intended to continue flight testing and evaluation of the civil systems and to support JTMLS and Shipboard Systems Advanced Development activity. Additional military funding for future years' activity that is beyond the scope of this prototype development plan will be included in future DOD budget requests to Congress. This will include requirements for other MLS derivative systems (such as the Air Transportable Cat II/III System) and for the Engineering Development (ED) phase of the military systems, including requirements such as conformance to Military Specifications and other preparations for entering the production phase.

2.4.3 Cost Growth

The original National Plan prepared in 1971 programmed funds over six fiscal years (1971 thru 1976). The Systems Development portion of this plan was contracted out to Industry for hardware development and was estimated to cost \$41 Million over the six year period. Inflation and program stretchout account for the increase to the present estimate of \$62.9 Million for that part of the plan.

In the Supporting Government Programs part of the Plan, two cost items are now included in the FAA program costs which were not included in the original plan. These are the $6.5M for Program Management and $18.6M for ICAO support. Plans to establish a Program Management Office were discussed in the original Plan but personnel costs for operating the Office were not included. Since the Program Office has been established, these in-house costs have been included in yearly budget submissions. The ICAO support costs, also, were not separately identified in the original National Plan. They are shown separately in this Updated Plan only to emphasize the expenditures that were associated with the submission of the TRSB system to ICAO for international standardization. Exclusive of these two items, the cost growth for Supporting Government Programs would be a moderate 12% above the 1971 planning estimate.

2.5 Program Management

2.5.1 FAA Program Management Office

The MLS program management structure is essentially as described in the July 1971 National Plan. The FAA Program Management Office is now within the Approach and Landing Division (ARD700) of the Systems Research and Development Service (SRDS). During the peak period this office included 23 full-time permanently assigned engineers supported by consultant/technical support services on an as required basis.

Although the size of the staff is being reduced, it is planned to maintain the FAA Program Management Office as long as FAA is involved in the management of prototype development contracts of the various MLS configurations and the test and evaluation activities of civil systems. The Program Management Office will be phased out as the development contracts are completed and the test and evaluation activities of the civil systems are completed. The final product of the civil development program will be the production specifications, which will be included as a part of a Technical Data Package provided to Airways Facilities Service for use in production procurement.

Active, essentially full-time, participation in the FAA Program Management office by all three military services and NASA has been maintained throughout

the program. When Program Management of the military system development activities are assumed by the military services, as described herein, it is planned that FAA will maintain technical liaison with their offices in much the same manner. The FAA will continue to maintain control over system standardization and signal format architecture.

The Inter-departmental Advisory Group was formed to assist the FAA Program Office in performance of MLS program integration and coordination responsibilities. This group functioned in the coordination of supporting Government programs and provided representation on technical evaluation teams during appropriate stages of the MLS development effort. The activities of this group have been completed and the group has been dissolved.

2.5.2 Military Lead Service

On September 10, 1976, DOD designated the U.S. Army as Lead Service Program Manager for the Joint Tactical Microwave Landing System (JTMLS) Program. In turn, the Army designated the Program Manager for Navigation/Control Systems (NAVCON) as Lead Service Program Manager. PM NAVCON is the primary DOD point of contact for all matters pertaining to JTMLS. Other military services will be assigned Lead-Service responsibility for development of other military MLS systems. As an example, the Navy will be assigned Lead-Service responsibility for the development of MLS for shipboard application.

Recent discussions between the DOD, FAA, and Congress have defined an intent to transfer management and budget responsibility for military development to DOD. This transition if approved, is to be implemented as soon as possible and FAA funds now programmed for military developments will be transferred to DOD. The Military Lead Service will maintain close coordination with the FAA to ensure that the military equipment developed will meet MLS standards. The FAA, on the other hand, will establish and maintain continued management controls over the MLS standard signal format. This will be done in coordination with a joint user group to ensure continued interoperability between air and ground units of civil and military operators.

3.0 NATIONAL AND INTERNATIONAL COORDINATION

This section discusses the following subjects:

- The general need for coordination and liaison among concerned government agencies and the aviation community.
- National coordination, both civil and military, and
- International Coordination.

3.1 General Need for Coordination

The development and implementation of a new civil/military microwave landing system involve various segments of government as well as the users of the system. Coordination activities are required to effectively accomplish the development effort and to prepare for integration of the new system into the NAS. These activities range from the dissemination of information on the nature of the effort, to the technical involvement of industry in the resolution of remaining issues and the participation of user groups in operational evaluations and demonstrations.

An equally significant consideration in the development of a new landing system for common civil/military application is the need to attain adoption of the system as an international standard. Past experience in introducing system changes into the international environment has illustrated the difficulty of obtaining agreement on the needed changes. It has also led to the realization that international collaboration starting at the earliest possible stage and continuing throughout the development process is essential. Therefore, it is necessary to plan for a coordinated effort throughout the development program. Additionally, it is desirable to seek the active participation of foreign governments and industry in the development work as a method of facilitating eventual worldwide agreement and acceptance.

3.2 National Coordination

Since the start of the MLS Development Program in 1971 it was recognized that the best way to fulfill the need for coordination expressed in Section

3.1 was to conduct the program with complete openness and candor. As a matter of policy, any interested aviation group should have access to monitor program progress and to provide comments and recommendations for change. That policy of openness has been followed up to the present time and will continue to be followed for the duration of the development effort. The principal forums that were used to obtain national coordination in the period 1971 to the present time are discussed below. These are in addition to many other discussions and presentations that included two international symposia, numerous articles in professional journals, presentations to technical societies, and the publication of several descriptive MLS brochures.

3.2.1 RTCA

The relationship of the Microwave Landing System (MLS) to RTCA can be considered a special one since the MLS development program stems directly from the work of that body. SC-117, which worked from 1967 to 1971, made several contributions that were vital to the success of the MLS program. These were:

- The consolidation of Operational Requirements through deliberation with the many aviation user groups;
- A review of state-of-the-art technology and a preliminary definition of signal characteristics;
- The identification of the most promising concepts, i.e. Scanning Beam and Doppler; and
- The recommendation that an MLS development program be undertaken by the government.

It is noteworthy that the Statement of Operational Requirements completed by SC-117 in 1971 is as valid in 1978 as it was when it was prepared. More recently a second RTCA Special Committee was formed, SC-125, Microwave Landing System Implementation. The terms of reference for this committee were to "provide user recommendations for a national implementation policy for MLS." The Committee completed its report in July 1977.

Each RTCA Annual Fall Assembly Meeting since 1971 has included a report of progress on the MLS program. This has been an effective means of disseminating program information to a large segment of the aviation community.

In the future, RTCA can be expected to prepare Minimum Performance Standards (MPS) and Minimum Operational Characteristics (MOC) as it has traditionally done for general aviation avionics.

3.2.2 MLS Advisory Committee

The original National Plan indicated that an advisory group would be formed from the nucleus of RTCA Committee SC-117 to provide advice and guidance. Accordingly, the FAA asked for and received recommendations from RTCA for appropriate membership. The Microwave Landing System (MLS) Advisory Committee was then officially formed in May 1973 with the approval of the Secretary of Transportation. Its charter provides for review of the development efforts and advising the Federal Aviation Administration regarding the feasibility of such activities; keeping informed of the operational needs of the users; recommending government and industry studies, tests, and simulations to verify the system capability for satisfying the operational needs of the users; and providing advice and ideas on, or methods to achieve solutions to, technical problems and concept choices.

The Committee was composed of approximately 20 operational and technical experts drawn from major user organizations - airlines, pilots, general aviation, and military; and a few widely recognized experts who represented the public interest.

The Committee, which held ten meetings, had a significant impact on the MLS program. It afforded the aviation user community with a direct and continuing means to critique this ongoing national program and to recommend changes in a timely manner. As a consequence, the Committee has been involved in all major program decision points, such as the one at which the Time Reference Scanning Beam (TRSB) system technique was selected.

With the AWOP decision to recommend TRSB for ICAO standardization, the work of the Committee was essentially completed. Accordingly, in keeping with the desires of the present Administration to reduce the number of Federal Advisory Committees, the MLS Advisory Committee was terminated.

3.2.3 IGIA Reviews

Another important means of national coordination has been through the Interdepartmental Group on International Aviation (IGIA). This is the body through which the State Department obtains coordination on the positions that the U.S. will take at international aviation meetings. It provides a broad representation of aviation interests in the U.S. The formal U.S. proposal to ICAO of the TRSB system was coordinated within IGIA.

3.2.4 Central Assessment Group (CAG)

One of the most significant milestones of the MLS development program was the selection of the "best" technique and associated signal format with which to enter into Phase III (Prototype Development). In order to inspire confidence within the aviation community and provide the basis for wide acceptance of the system selected, both nationally and internationally, a group of specialists was formed to participate in this selection. This Group was known as the Central Assessment Group (CAG) and was composed of over 100 landing system operational and technical experts from participating Government organizations (national and international), as well as manufacturing and user groups. The selection was made in an open and participative environment. The CAG recommendations were reviewed by the MLS Executive Committee, composed of senior executives from the participating U.S. Government agencies. This Committee endorsed the recommendations of the CAG and made the final technique/signal format decisions which formed the basis for the Phase III program and the U.S. system proposal to ICAO.

3.2.5 ATA, AOPA, NBAA, ALPA, AOCI, etc.

Each of these organizations has been very active in the MLS program. Most of them were represented on the MLS Advisory Committee and participated in a number of technical symposia and flight demonstrations. They have been regular attendees at the Annual FAA Planning Review Conferences where progress reports and discussion on MLS took place. It is anticipated that their

participation will become intensified during any field tests and evaluation activities that may be conducted on the TRSB MLS.

3.2.6 ARINC/AEEC

Now that TRSB has been selected by the All Weather Operations Divisional Meeting of ICAO for international standardization, it is expected that ARINC/AEEC will become more active in preparing airline avionics standards and specifications.

3.2.7 DOD

The Military Services have been active participants in every major activity in the MLS development program. This has included representation on evaluation groups, the MLS Advisory Committee and the MLS Executive Committee. Liaison officers have been on full time assignment in the FAA MLS Program Office since its formation in 1971. The MLS Supporting Government Programs conducted by the Services have been a vital portion of the MLS development effort.

3.2.8 Focus of Future National Coordination

For the future, the FAA will continue to carry out the policy of openness of the MLS TRSB program. Although the MLS Advisory Committee is no longer in existence, much of the future coordination is expected to take place in IGIA, RTCA, and, of course, ICAO. For example, the next major milestone in the ICAO program for a new landing system is the preparation and approval of SARPS (Standard and Recommended Practices) for TRSB. The U.S. work on SARPS will be initially coordinated through IGIA. In addition, the FAA will continue to seek methods to inform and obtain comments from U.S. aviation interests as the MLS program progresses, and, finally, any implementation or regulatory activity would be pursued using standard administrative procedures which provide for full public notice and comment.

3.3 International Coordination

3.3.1 International Civil Aviation Organization (ICAO)

At about the same time that RTCA SC-117 was completing its recommendations for a new approach and landing system, parallel action was developing within ICAO. The Air Navigation Commission assigned the All Weather Operations Panel (AWOP) the task of assessing the limitations of ILS, and if considered necessary, developing an operational requirement (OR) for a replacement system. AWOP concluded that a new approach and landing guidance system was needed, finalized a draft OR, and proposed an ICAO program aimed at the adoption of a new ICAO standard non-visual precision approach and landing guidance system by mid 1976.

At the 7th Air Navigation Conference, in April 1972, the operational requirements were officially adopted and an appropriate 3 Stage development program was approved. Member States were invited to submit proposals for systems which would satisfy the OR. AWOP was designated as the ICAO instrument for completing Stage 1 of the process; that is, for screening submissions, assessing their ability to meet the OR, and preparing a recommendation for the ICAO standard system. Initial system proposals were received in early 1973 from five States: Australia, Federal Republic of Germany, France, United Kingdom, and United States. In November 1973, AWOP set up an internal working group, WG-A, charged with the task of assessing the five contending systems.

AWOP, WG-A, first agreed on such things as ground rules for the assessment, evaluation criteria, submission format, standardized test requirements and assessment methodology. Final system proposals were then requested by July 1, 1975, and subsequently postponed to December 1, 1975, following a request for a six month delay from the Federal Republic of Germany.

AWOP WG-A then held a series of meetings to assess the proposals in Braunschweig, February 1976; Washington, D. C., May 1976; the Hague, July 1976; and London, November 1976. Performance data continued to be made available during this period and changes in systems design were proposed as a result of improvements made during the assessment process. However, by mutual agreement, system designs were frozen as of November 1, 1976. During the

assessment it was determined that the French proposal for an Air Ground Data Link System was not a complete system proposal fully responsive to the OR, and consequently was not carried further in the Panel's assessment of contending systems. Also, the Panel agreed to deal jointly with the U.S. proposal for a Time Reference Scanning Beam (TRSB) system and the Australian proposal for an Interscan system, since their signal formats were essentially identical, and research results were mutually complementary.

At its sixth formal panel meeting in March 1977, the Panel completed the assessment of proposed systems and recommended that TRSB be selected for international standardization.

The Air Navigation Commission (ANC) then reviewed the AWOP work and concluded that the Panel had successfully completed its assigned task, thereby bringing Stage 1 of the ICAO program to a close.

The ANC then submitted the Panel's recommendation to the ICAO Council and recommended, in turn, that a Worldwide Meeting be convened to accomplish Stage 2, the selection of a system for international standardization. The ICAO Council then approved the ANC recommendation and scheduled an All Weather Operations Divisional (AWOD) Meeting to be held in Montreal in April 1978, for the purpose of selecting a new international precision approach and landing guidance system.

In April 1978, the AWOD meeting, of 71 ICAO States, voted, by secret ballot, to select the TRSB system. It further recommended that the ANC should now assign the AWOP the task of developing Standards and Recommended Practices (SARPS) for this system for inclusion in ICAO Annex 10. Thus, Stage 2 of the ICAO program has been completed and Stage 3 is being initiated. Stage 3 involves the further development of SARPS and guidance material for ground and airborne equipment for presentation to and acceptance by a world-wide ICAO meeting. The final goal would be the publishing of this material in the appropriate annex to the Convention on International Civil Aviation. According to the ICAO timetable, this process can be expected to take approximately 18 months.

3.3.2 North Atlantic Treaty Organization (NATO)

The U.S., thru the Department of Defense, has continued to keep the interested parties of NATO informed on the overall MLS development and testing program. The U.S. has participated in several meetings of the NATO Air Force Armaments Group (NAFAG) Sub-Group 7 concerned with technical-operational interchange and position discussions concerning a new international standard military-civil MLS. The European NATO countries are keenly aware of, and concerned with the selection and development of a common military-civil MLS, due to a large extent, to the large number of NATO joint useage civil-military airfields. Of continuing interest to the NATO countries is the ability of the ICAO-selected new international standard MLS, developed in accordance with the ICAO MLS Operational Requirements (OR) document, to meet and/or be adaptable to the operational requirements specified in the NATO MLS OR document. With the selection of the TRSB MLS as the new international ICAO standard, dedicated U.S.-NATO actions and meetings will be undertaken to determine if the new international standard MLS can meet the NATO OR. Continuing U.S. effort will be required in this area of endeavor, along with the development of a meaningful and responsive U.S.-NATO Implementation Plan.

4.0 TRANSITION TO THE NEW LANDING SYSTEM

This section identifies the alternative methodologies that might ultimately be employed for MLS implementation, rather than presenting a specific plan for implementation. The specific timing for initiating MLS will be predicated on domestic needs which may arise, but in any case, will be conducted in a way which is harmonious with international efforts to complete MLS Standards And Recommended Practices (SARPS). International opinion will be sought with respect to any actions where there may be sensitivity and every effort should be made to avoid actions that might disrupt the multilateral ICAO process.

In this regard, the FAA believes it is premature to solidify implementation plans at this time since unilateral action in this regard could be misunderstood by the international community.

4.1 National and International Implications

It is clearly the intention of the United States and the other nations of the world to implement the newly selected replacement for ILS. The requirement for this system, which has been the subject of unparalleled multilateral development and assessment since 1972, is recognized around the world and was reaffirmed by a worldwide meeting of ICAO States in 1978. However, it is also recognized that the system which MLS will eventually replace (i.e., ILS) has been widely implemented, is providing good service in many locations around the world (approximately 600 in the U.S. alone) and has a large user community with many thousands of aircraft equipped to use it. Thus, in making any MLS implementation decision, the provider of landing system service (normally the Government) must consider not only its investment and the improvement in service, but also the effect on the user in terms of his investment and his improvement in service. The decision is the responsibility of the individual Government involved and is made or deferred in recognition of domestic concerns except as regards those particular runways which are internationally "advertised" by the country (at international airports) through publication in an

ICAO Regional Plan. In those cases, and those cases alone, living up to an international commitment requires that an ILS (either alone or collocated with an MLS) be maintained until such time as its "protection" is no longer guaranteed by ICAO.

This does not mean that the U.S. is prohibited from taking advantage of the attributes of MLS to the extent deemed advantageous for domestic (civil and military) purposes so long as the nearly 100 "advertised" facilities are also kept in service. Essentially, each country must decide for itself, the major question of implementation of the new system, but in the case of retirement of the old system, a commitment to the international community must be respected at least until 1995.

In addressing this question, the U.S. will be very sensitive to the pace of international MLS implementation. It will actively attempt to work in concert with the world aviation community so that any actions will have a synergistic effect on aviation safety and not be a disruptive influence, while at the same time, ensuring that domestic needs are addressed.

In the near term, the ICAO process (See Section 3.3.1) continues to operate with the inauguration of Stage 3 (Development of SARPS). This stage will take approximately 18 months and will culminate in a worldwide ICAO meeting. Not until this stage is over will the specific technical parameters of TRSB system operation be fully agreed so that no risk is involved in building hardware. Thus, the U.S. does not anticipate the need to make final hardware decisions regarding civil Government implementation until Stage 3 is complete. In the interim, the U.S. and many other nations must and will address the policy, regulatory, technical and economic aspects of transition and implementation planning which necessarily precedes final hardware decisions. These matters are discussed below.

4.2 Handoff From Development to Implementation

The MLS development effort has been a national program jointly sponsored by the DOT, DOD, and NASA with the FAA designated as the management agency. While there are differences in the management of major systems as practiced within the DOT, DOD, and NASA, the civil aviation aspects of the MLS program

are being pursued in accordance with FAA procedures. These procedures are described in FAA Order 1810.1A, System Acquisition Management (SAM), dated March 14, 1978.

Since the issuance of the initial National Plan for the Development of the MLS in 1971, the large preponderance of effort has been devoted to the system development. That activity is now nearing completion. There are a number of second order technical questions that remain to be resolved, yet the major features of the system design and signal format have been sufficiently tested and evaluated to proceed with confidence to the activities that will be discussed in this section.

The FAA Order on System Acquisition Management makes provision for a Transition Plan for major development programs that will eventually involve the establishment and operation of many facilities and services. The MLS program has been designated as a major FAA system acquisition and a Transition Plan is being prepared. The Transition Plan indicates the results of MLS development work together with studies on alternative courses of action that will provide the basis for an implementation decision. The Implementation Plan in turn, lays out the single approved course resulting from the decision. Before adoption, the FAA intends to seek comments on both plans from user and other interested groups, in line with its consultation policies on all major FAA programs.

Since there are presently no commissioned MLS facilities it is envisioned that the hand-off from development to implementation could be facilitated through a Service Test and Evaluation Program (STEP) which will involve user participation at selected operational field facilities.

In the STEP a number of MLS installations would be deployed for operational demonstration so as to provide the aviation users and the providers of service with the opportunity for first hand operational experience. This would be a means of transferring MLS technology to FAA offices which would be responsible for its operation and implementation. STEP would make it possible to refine standards and procedures for installation, commissioning, flight inspection, maintenance, logistics, monitoring, reliability and training. This approach is also expected to find favor with some of the international community who face similar problems themselves. International opinions and participation will be solicited in formulating a STEP program.

For the implementation of MLS that would follow STEP, a number of installation alternatives (strategies) have been postulated, each focusing on a specific objective. However, no consensus has been reached as to their relative merits, no comparative evaluation is made and no recommendations are formed. Nevertheless, some of the more pertinent points associated with each strategy are presented herein for preliminary consideration.

The combined initiation of the STEP effort and the analyses of follow-on implementation alternatives would be the first stage of the implementation process. It would be through this process that an effective and equitable implementation could evolve, which draws upon the best available operational experience.

It should be noted that there are civil public-use navigation and landing facilities used for IFR flying which are not owned and operated by the FAA. These facilities, known as "Non-Federal" aids, are certified by the FAA under the provisions of Federal Aviation Regulation (FAR) 171. Thus, aside from the issuance of the appropriate FAR 171 revision, implementation of Non-Federal aids is not a program which the FAA will manage.

4.3 System Implementation

As indicated previously, it would be premature to define a firm implementation strategy at this stage of the MLS program. While considerable study and analysis has already been performed on MLS implementation strategies, it cannot be said with assurance that any one strategy or combination of strategies would be desirable.

An FAA Working Group, chaired by the Office of Aviation Systems Plans reviewed and developed a number of strategies for possible consideration in transition planning. As its starting point, the Working Group reviewed the strategies prepared by RTCA Special Committee 125 (MLS Implementation). It then developed a number of strategies of its own. The principal strategies that were considered are described below.

Strategy 1. New-Qualifier Airports and Baseline* Deployment - Install MLS first at new-qualifier airports and then per the Baseline Option. $20 million annual F&E funding limit.

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*Installation of MLS's in order of Annual Instrument Approach (AIA) ranking.

Strategy 2. New-Qualifier Airports, New-Qualifier Runways at Equipped Airports, and Baseline Deployment - Install MLS first at new-qualifier airports, then at new-qualifier runways at airports that already have at least one precision landing system, and finally per the Baseline Option. $20 million annual F&E funding limit.

Strategy 3. Upgrading to Category II/III, New-Qualifier Airports and Baseline Deployment - Install MLS first at airports that qualify for upgrading from Category I to Category II/III or from Category II to Category III, then at new-qualifier airports, and finally per the Baseline Option. $20 million annual F&E funding limit.

Strategy 4. Funding Split Among Network Airports, New-Qualifier Airports, and Baseline Deployment - Allocate first one-third of annual F&E funding to network airports, next one-third to new-qualifier airports, and last one-third for baseline deployment. $20 million annual F&E funding limit.

Strategy 5. Upgrading to CAT II/III, New-Qualifier Airports, and Baseline Deployment - Same as Strategy No. 3 except $50 million instead of $20 million annual F&E funding limit.

Strategy 6. New-Qualifier Airports, New-Qualifier Runways at Equipped Airports, and Baseline Deployment - Same as Strategy No. 2 except $50 million instead of $20 million annual F&E funding limit.

Strategy 7. Upgrading to Category II/III, New-Qualifier Airports, New-Qualifier Runways, and Baseline Deployment - Install MLS first at airports that qualify for upgrading from Category I to

Category II/III or from Category II to Category III, then at new-qualifier airports, then at new-qualifier runways at airports which already have at least one precision landing system and finally per the Baseline Option. $20 million annual F&E funding limit.

Strategy 8. New-Qualifier Airports, Noise-Sensitive Runways, New-Qualifier Runways, and Baseline Deployment - Install MLS first at new-qualifier airports, than at noise-sensitive runways, then at new-qualifier runways at airports which already have at least one precision landing system, and finally per the Baseline Option. $20 million annual F&E funding limit.

Strategy 9. New-Qualifier Airports, New-Qualifier Runways, ILS Tube-Type Replacement, Upgrading to CAT II/III, and Baseline Deployment - This implementation strategy is divided into three phases. During the initial phase (1980-82), MLS's are installed first at new-qualifier airports, then at new-qualifier runways, then as replacements for ILS tube-type systems and finally per the Baseline Option. During phase 2 (1983-87), the first three options remain the same as in phase 1 and the fourth option is to install MLS at airports that qualify for upgrading from CAT I to CAT II/III or from CAT II to CAT III and the Baseline Option becomes the fifth option. During the final phase (1988-2000), MLS installation is the same as in phase 2, except the ILS tube-type replacement option is deleted. $20 million annual F&E funding limit.

Strategy 10. Aviation User Implementation Strategy (RTCA SC-125 - In addition to the nine implementation strategies discussed above, the following strategy was submitted to the FAA by RTCA Special Committee 125 for consideration.

The basic objectives of this strategy were to maximize user benefits (especially in the short term), and generate program momentum by making user

equipage an attractive option. The strategy is divided into three time periods - short, middle, and long term - and may be summarized as follows:

Short Term

Develop a list of hub airports with wide-body aircraft service, rank ordered on the basis of total itinerant operations. Around each of these hub airports a network of airports would be developed within approximately 500 miles of the hub airport. Beginning with highest ranking airport in the network, a single MLS would be installed in the following order:

- The hub airport around which the network is developed
- Network airports without precision guidance served by commuter and/or regional air carriers
- Small Community airports that do not have precision approach guidance instrumentation and have 400 or more annual instrument approaches (AIAs)
- Airports with trunk service.

Middle Term

- Install MLS at network airports that were not implemented in the short term due to the 50 percent cutoff criteria, rank-ordered on the basis of AIAs
- Install MLS at locations with 400 or more AIAs (rank ordered by AIAs)
- Install MLS systems at ILS sites.

Long Term

The long term approach is to install MLS at runway ends with 400 or more annual instrument approaches in rank order of their AIAs or any other acceptable measurement of runway usage by equipped aircraft.

4.4 Conclusions

Once the Transition and Implementation Plans have been developed and adopted, the phasing and form of MLS implementation will be finally determined through the regular federal budgetary process and will reflect, of course, budget priorities of both the Executive Branch and the Congress.
The machinery to enable private investment in the provision of facilities (i.e., FAR 171) and their use within the U.S. for civil aviation will be considered under statutory authority of the FAA utilizing normal administrative processes which provide full opportunity for public comment and participation.

Addressing the combined efforts of STEP and analyses of implementation alternatives which is embodied in the Transition Plan is the first part of the implementation process. It is through this process that an Implementation Plan can evolve.

The overriding interest in the U.S. is to continue the international process of standardization in a smooth and harmonious fashion. This being the case, in considering the approaches toward implementation including any STEP activity and the revision of FAR 171, the advice of the international community will be sought so that U.S. actions consider the aims of our international allies, neighbors, and partners.

5.0 REFERENCES

1. The National Plan for Development of the Microwave Landing System, FAA Report No. FAA-ED-07-2, dated July 1971.
2. FAA Order 1810.1A, Systems Acquisition Management

APPENDIX A

TRSB SYSTEM DESCRIPTION [1]

[1] This Appendix, which describes the Time Reference Scanning Beam Microwave Landing System, is a copy of Section 1.0, Introduction and Summary, of the United States formal proposal to ICAO for "A New Non-Visual Precision Approach and Landing Guidance System for International Civil Aviation."

U.S. PROPOSAL FOR

A NEW NON-VISUAL PRECISION

APPROACH AND LANDING GUIDANCE SYSTEM

SECTION 1.0

INTRODUCTION AND SUMMARY

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1.0 INTRODUCTION AND SUMMARY

The United States (U.S.) Proposal (reproduced by the ICAO Secretariate as AWOP-WP/262) presents a detailed description of the Microwave Landing System (MLS) proposed by the U.S. to meet the international need for a new standard Non-Visual Approach and Landing Guidance System. The general outline of the proposal conforms to the guidance recommended by the ICAO All Weather Operations Panel (AWOP) and presents an MLS that meets the ICAO operational requirements.

The U.S. approach to MLS is based on the Time Reference Scanning Beam (TRSB) technique, which evolved from more than 15 years of development effort on scanning beam systems. In addition to this extensive practical background in scanning beam systems, a comprehensive program of comparative studies of scanning beam and Doppler scan landing system techniques was begun in 1971. This work included the design and test of competitive hardware implementations so that practical experience with various design approaches could be gained. After a thorough assessment of the results of this work, the U.S. selected the TRSB technique in 1975 as its candidate for consideration by ICAO in accordance with the program approved by the ICAO Council based upon 7th Air Navigation Conference Recommendation 3/5.

At the conclusion of its own comprehensive assessment of all the candidate systems proposed by the participating States, the All Weather Operations Panel decided to recommend that the signal format of the U.S. TRSB and Australian "Interscan" system submissions be recommended by ICAO to the planned All Weather Operations Divisional Meeting for international standardization and adoption.

1.0.1 System Overview

The U.S. Time Reference Scanning Beam (TRSB) is an air derived system in which ground based equipments transmit position information signals to a receiver in the landing aircraft. The position information is provided as

angle coordinates and a range coordinate. The angle information is derived by measuring the time difference between the successive passes of highly directive narrow fan-shaped beams inherently providing an accurate means for the time measurements. The range information is provided by the Distance Measuring Equipment (DME) technique.

The TRSB signal format is time-multiplexed, that is it provides information in sequence on a single carrier frequency for all the angle functions (azimuth, elevation, flare and missed approach azimuth). The format includes a time slot for 360° azimuth guidance with provision for growth of additional functions. The angle guidance channel plan provides 200 C-band channels spaced 300 KHz apart, in 60 MHz between 5031 MHz and 5091 MHz. The range channel plan also has been defined to provide 200 channels.

Narrow fan-shaped beams are generated by the ground equipment and scanned electronically to fill the coverage volume. In azimuth, the fan beam scans horizontally and has a vertical pattern that is shaped to control illumination of the airport surface. In elevation the arrays are designed to minimize unwanted radiation towards the airport surface thereby providing accurate guidance to very low angles. It is this ability to control the radiation patterns of the ground antennas that allows the use of simple airborne processing to achieve TRSB's high resistance to interference from signal reflections (multipath).

A ground-to-air data communications capability is provided throughout the angle guidance coverage volume by stationary sector coverage beams that are also designed to have sharp lower-side cutoff. This communications capability is used to transmit the identity of each angle function and to relay information (auxiliary data) needed for all weather operations.

The airborne equipment receives the ground generated sector and scanning beam signals associated with each angle function and in sequence, determines the identity of the angle function and then detects the scanning beam angle information. It subjects the received signals to acquisition criteria before they are accepted and continues validation following acceptance to provide reliable interference-free angle information.

The principal features of TRSB provide a system with accurate performance, high integrity and very straight-forward and low-cost implementation. TRSB

has a simple concept, easily visualized for its design, simulation and validation. It contains a single unmodulated transmitter channel for each function which results in high integrity and reliability.

The signal-in-space is highly stable by relying on digital techniques to generate the scanning beams, monitor the equipment, and process the guidance signals.

TRSB can be installed and commissioned with ease because of the absence of field adjustments in the antennas and associated equipment. Repair is simplified by the replacement of modules which require no further calibration to maintain continued accurate guidance. The TRSB ground equipment is monitored by a combination of field and integral monitoring to assure system performance and integrity, and provide the necessary maintenance alerts.

1.0.2 Design Principles

During the early years of development, certain principles were adopted as fundamental in the design of any future landing guidance system for widespread international use. These concepts have been incorporated in the proposed TRSB system as follows:

a. The system utilized techniques that help to solve multipath problems essentially on the ground and with a minimum requirement for airborne processing. That is, narrow fan-shaped beams are used (in the scanned plane) to separate the direct beam from reflected beams, while antenna pattern shaping is used (in the non-scanned plane) to limit the amount of signal energy that is radiated toward reflecting objects.

b. The system is designed to facilitate transition from the current ILS to the future MLS. The ability to physically collocate MLS with the existing ILS has been emphasized and successfully demonstrated.

c. The modularity concept has been prominent in all system design considerations as illustrated by the decision to make the DME function an independent system element. A major feature of TRSB modularity is that it permits implementation of very simple equipment for angle guidance and allows the use of conventional marker beacons instead of the more expensive DME.

d. The TRSB is an "air-derived" system in which position is measured directly in the aircraft, rather than relying on ground-derived data that is relayed from ground to air. Air-derived systems provide navigation information separate from any surveillance function, and thus, achieve an added measure of integrity through system independence.

e. In addition to meeting all currently stated requirements, TRSB has growth potential for meeting future needs, such as vertical guidance for missed approach or 360° azimuth coverage, should these become desirable.

f. Integrity and reliability are fundamental requirements associated with all-weather operations. The TRSB system, with its stress on simple transmitters, fail-soft antennas, and comprehensive monitoring fully meets these requirements.

1.1 System Fundamentals

This section describes the TRSB measurement technique and summarizes system operational capabilities as well as the functional characteristics established to achieve them. In addition, an overview of the signal format and its realization in hardware is given.

1.1.1 System Concept and Functional Characteristics

1.1.1.1 Angle Guidance

The TRSB signal format is based on the scanning beam technique in which narrow fan beams scan through the coverage volume in alternate directions (TO and FRO). The "TO" beam is scanned with uniform speed starting from one extremity of the coverage sector and moves to the other. The beam then scans back again to the starting point, thus producing the "FRO" scan as shown in figure A-1 for azimuth. In every scanning cycle, two pulses are received by the aircraft. The time interval between the TO and FRO pulses is proportional to the angular position of the aircraft with respect to the runway. An important feature of the time reference encoded scanning beam system is the high data update rate, 13.5 Hz for azimuth and 40.5 Hz for elevation. These rates

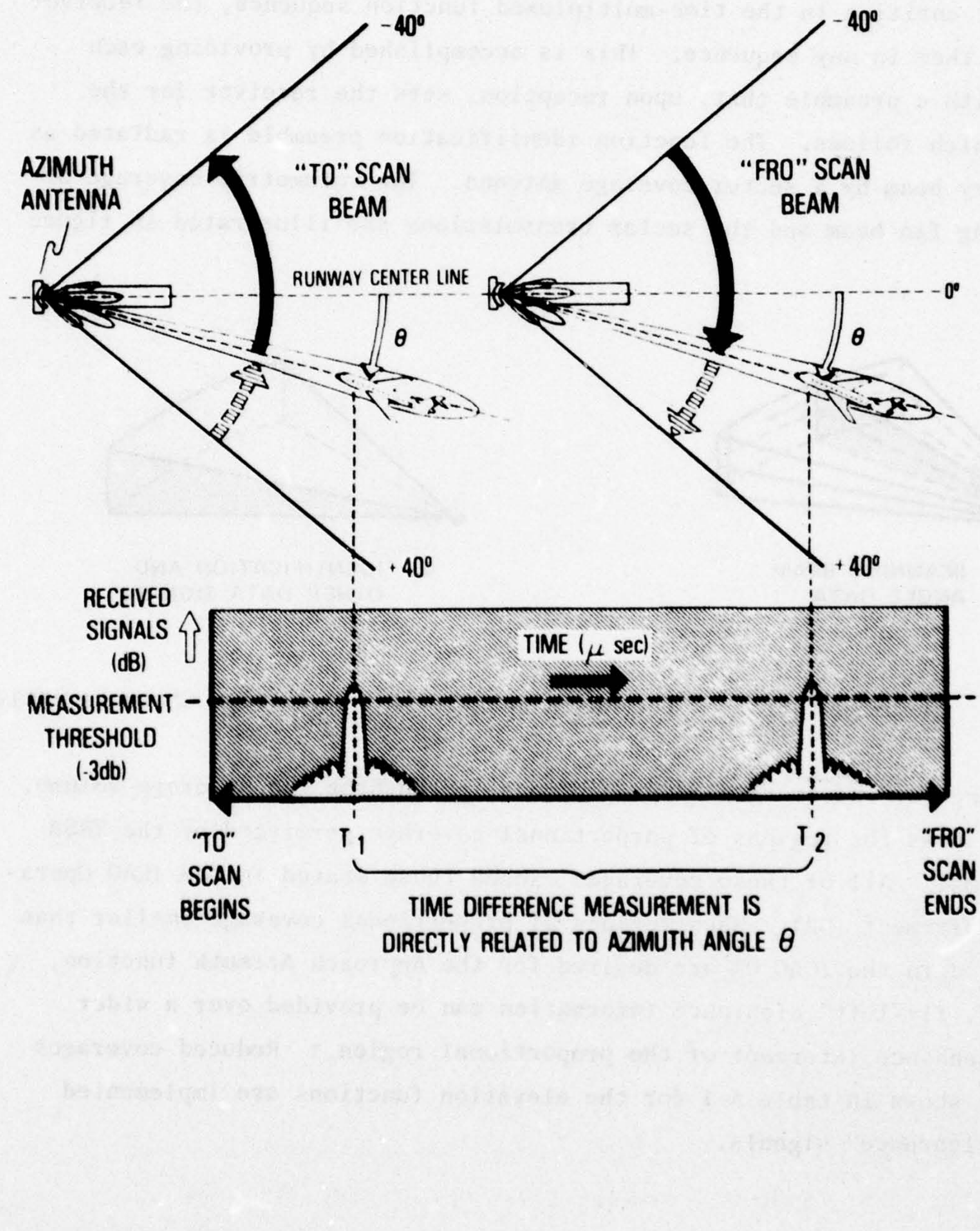


Figure A-1. Time Difference Measurement

permit the integration of individual measurement samples to achieve guidance information having a very small noise content.

All angle and data functions are time-multiplexed so that a single receiver-processor channel may process all data. Since the functions are independent entities in the time-multiplexed function sequence, the receiver may decode them in any sequence. This is accomplished by providing each function with a preamble that, upon reception, sets the receiver for the function which follows. The function identification preamble is radiated as a stationary beam by a sector coverage antenna. The volumetric coverage of the scanning fan beam and the sector transmissions are illustrated in figure A-2.

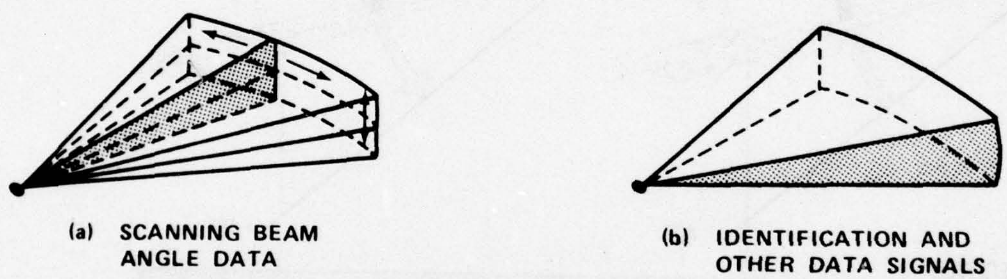


Figure A-2. Representation of the Angle and Preamble Radiation Characteristics

All angular information is proportional throughout the coverage volume. Table A-1 shows the regions of porportional coverage permitted by the TRSB signal format. All of these coverages exceed those stated in the ICAO Operational Requirement (OR). When regions of proportional coverage smaller than those stated in the ICAO OR are desired for the Approach Azimuth function, "fly-right, fly-left" clearance information can be provided over a wider sector to enhance intercept of the proportional region.* Reduced coverages from those shown in table A-1 for the elevation functions are implemented without "clearance" signals.

*For instance, a proportional approach azimuth coverage of ±10° could be implemented for general aviation use with "left-right" clearance signals to ±40° as in the U.S. Small Community configuration.

Table A-1. TRSB Coverage Capabilities

FUNCTION	PROPORTIONAL REGION
Approach Azimuth	±60°
Approach Elevation	0° to 30°
Flare	-1° to 15°
Missed-Approach Azimuth	±40°
Missed Approach Elevation[1]	0° to 30°
360° Azimuth[1]	360°

[1] Function not required by the ICAO OR

1.1.1.2 Range Determination

Range information is obtained in the conventional manner by measuring the round trip time between the transmission of interrogation pulses from aircraft and reception of corresponding reply pulses from a ground transponder. The ground transponder is typically located near the stop end of the runway collocated with the approach azimuth system. An L-Band Distance Measuring Equipment (DME that is compatible with existing equipment and provides improved accuracy and channelization capabilities is proposed for implementation. A range guidance function at C-Band has been developed and is included in the proposed TRSB signal format. This feature can be deleted if it is determined that L-Band DME is adequate. Marker beacons may be used to indicate progress on an approach by users who do not require DME services.

1.1.1.3 Flare Guidance

The TRSB signal format includes provision for a flare element in accordance with the ICAO Operational Requirement, which has been interpreted by AWOP to imply the need for precise guidance from eight feet above the runway surface throughout the touchdown zone. Automatic landings have been made

using the TRSB Approach Elevation signal and a radio altimeter, and this mode of operation is expected to be continued in the future. However, special or unusual circumstances can dictate the need for a separate ground-based flare capability. TRSB has demonstrated the performance necessary to meet the very demanding flare requirement stated in the ICAO OR using a combination of a narrow antenna beam, pattern shaping, and asymmetric signal processing.

1.1.1.4 Data

The TRSB system has a very versatile data communications capability. Data are transmitted to all aircraft within the coverage volume (figure A-2) using Differential Phase Shift Keying (DPSK) modulation. These signals are time-multiplexed with the angle functions. (Refer to Paragraph 1.2.11 (h).) Much growth potential is available in the TRSB data format.

1.2 Summary of Basic Features

TRSB was developed in response to a well-known need for an improved landing system. This section presents a brief overview of the operational applicability to the ICAO requirements.

1.2.1 Siting Flexibility for Universal Implementation

Site preparation required to provide a suitable signal will be minimal for TRSB, since microwave frequencies allow for the use of narrow beams and controlled antenna patterns, thus reducing unwanted radiation toward the ground.

Buildings and terrain features that cause reflections do not cause significant interference. When the scanning beam illuminates the receiving aircraft and a reflecting object simultaneously, the multipath interference is called "in-beam". The high data rate of TRSB provides an effective solution by the natural averaging that takes place in the receiver. Other reflections are called "out-of-beam". The use of narrow scanning beams on the ground combined with receiver thresholding and time-gating, protect the system from out-of-beam effects.

The out-of-coverage indication (OCI) provision in the signal format prevents unwanted flag action outside the system coverage volume.

To cope with extremely adverse multipath cases that would impare the functioning of any form of MLS, TRSB has the additional capability of avoiding illumination of the troublesome object by a simple adjustment of the scan coverage limit.

1.2.2 Applicability to All Aircraft

TRSB spans the entire range of approach and landing operations for all known aircraft types. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. A wide range of approach speeds (to 600 kts.) are facilitated by the narrow system bandwidth which easily accomodates the expected range of Doppler shifts caused by aircraft motion relative to the ground station. Further, very low approach speeds (including a hover condition) are accommodated so that under even difficult multipath conditions, the output information will have a very low noise content. The particular needs of users ranging from general aviation to major air carriers are accommodated. TRSB is adaptable to special situations, such as transportable or shipboard configurations.

1.2.3 Interoperability

The TRSB universal signal format ensures that every airborne user may receive landing guidance from every ground installation. Interoperability is also provided between facilities serving international civil aviation and those serving unique national requirements.

1.2.4 Flight Path Flexibility

The TRSB wide proportional coverage provides aircraft flight path flexibility as well as easy transition from en route navigation. The flexibility in approach paths, coupled with high-quality guidance, can be used to achieve:

a. Increased runway and airport arrival capacity

b. Control of noise exposure near airports

c. Optimized approach paths for future V/STOL aircraft

d. Intercept of glide path without overshoot and intercept of runway centerline extended without overshoot

e. Lower minimums at many existing airports by providing precise approach and missed-approach guidance.

1.2.5 Expanded All-Weather Service

TRSB can provide all-weather landing facilities at many runways that presently do not offer this service. This is made possible by the microwave channel plan, which contains enough channels for any forseeable implementation, and by the siting flexibility discussed in 1.2.1.

TRSB will enable landings under Category III conditions to become more widespread. Improved guidance signal quality will improve path following and reduce touchdown dispersion.

1.2.6 High System Integrity

The high reliability, integrity, and safety of TRSB are enhanced by several important features:

a. Signal format features such as parity and symmetry checks prevent the possibility of confusion or functions.

b. Simple transmitter and receiver implementations increase reliability; fail-soft ground-based antennas increase system availability.

c. Multipath immunity features on the ground in addition to acquisition and validation procedures in the receiver assure reliable interference-free output information.

d. Signal format randomization (whereby the sample period of each function is staggered) prevents synchronous interference.

e. A comprehensive monitoring system verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft from two to six times each second.

1.2.7 Modular Flexibility

The providers and users can implement the needed level of service at minimum cost because of the modularity of the signal format and available hardware implementations.

With regard to hardware modularity, the TRSB technique allows a variety of ground antennas with differing performance levels and coverages to be implemented. Thus, the user can choose a cost-effective implementation based on runway length, multipath environment, topography, and category of service desired. The airborne user likewise has a variety of services and capabilities to choose from.

A feature of the TRSB format is the ability to provide split-azimuth facilities (one on each side of the runway) which can be installed at runways where the vertical profile would shadow the azimuth signal to an aircraft near touchdown, or where there is not sufficient room at the stop end of the runway to accommodate a conventional siting arrangement.

1.2.8 Low-Angle Elevation Coverage Capability

The TRSB concept and design provides excellent low-angle coverage essentially from ground level to the extremes of coverage established by the signal format.

1.2.9 Spectral Efficiency

The TRSB angle coding structure enables narrow bandwidth operation and the use of low transmitter power.

1.2.10 System Growth

Time-multiplexing and the optimum function times used in the TRSB signal format make it outstanding in its ability to adapt to possible future requirements.

a. Projected future requirements for 360° azimuth and for missed-approach elevation are already incorporated in the format.

b. Future function requirements may be accommodated by defining additional functions using spare function identification words.

c. Future or special national requirements for additional auxiliary data words may be accommodated by using spare data word addresses. Additional auxiliary data words are easily incorporated in the time-multiplexed TRSB signal format.

d. The high angle data sampling rate ensures that new high-performance aircraft employing techniques such as direct lift control will not be constrained by data bandwidth limitations.

1.2.11 Signal Format

The TRSB signal format has been carefully structured and fully validated in representative hardware; it is mature and warrants ICAO endorsement.

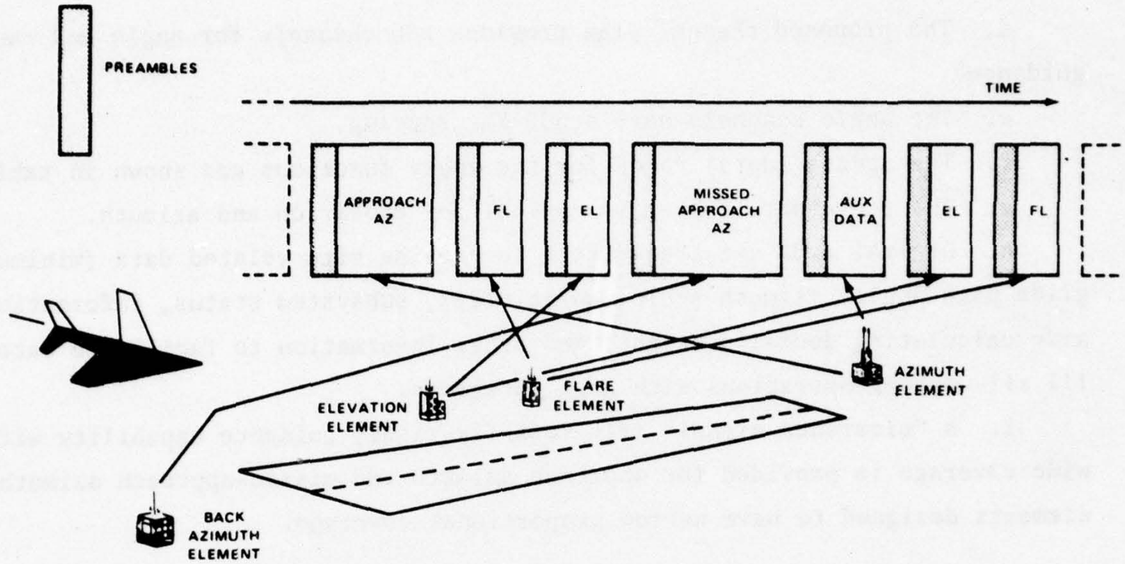
Figure A-3 illustrates a portion of the TRSB time-division-multiplexed (TDM) signal. The various functions are sequentially radiated on the same frequency. The receiver identifies each function by its preamble and then decodes the scanning beam information. The technique is flexible in that any combination of functions may be radiated by ground stations and arranged in any order without affecting proper operation of any receiver, and alternate arrangements may be employed to meet special national requirements. The features of the TRSB signal format intended for international use are listed below:

a. The format provides the following guidance functions:

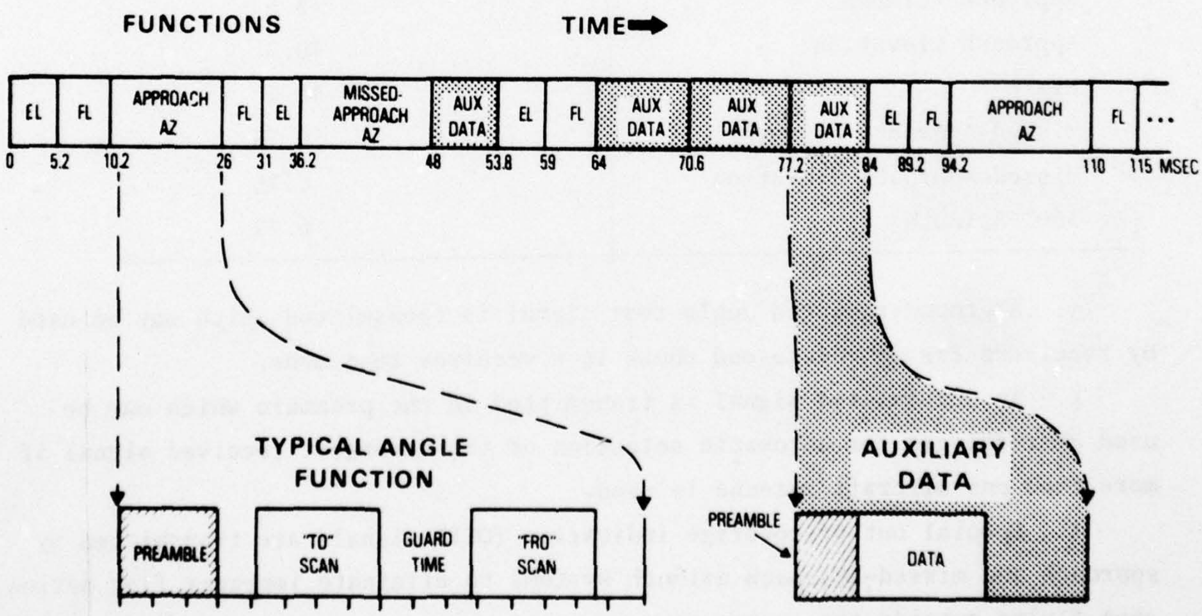
(1) Approach azimuth
(2) Approach elevation
(3) Range, using a compatible DME
(4) Missed-approach azimuth
(5) Missed-approach elevation
(6) Flare
(7) 360° azimuth

b. The radio frequency allocation for angle guidance is at C-Band from 5031 MHz to 5091 MHz.

c. Signal polarization is vertical.



(a) Time-Division-Multiplexed Sequencing of Function Signals



(b) Typical Expanded System Frame Period and Details of Two Representative Functions

Figure A-3. Time-Division-Multiplexed Function Signal Format

d. The proposed channel plan provides 200 channels for angle and range guidance.

e. The angle channels have a 300-KHz spacing.

f. The update (data) rates for the angle functions are shown in table A-2.

g. The coordinate system is conical for elevation and azimuth.

h. Digital data are transmitted to provide site related data (minimum glide path angle, azimuth scale sensitivity), subsystem status, information to aide calculating decision height, and other information to facilitate Category III all-weather operations with high integrity.

i. A "clearance signal" (fly-left/fly-right) guidance capability with wide coverage is provided for approach azimuth and missed-approach azimuth elements designed to have narrow proportional coverage.

Table A-2. Angle Function Update Rates

FUNCTION	UPDATES PER SECOND
Approach Azimuth	13.5
Approach Elevation	40.5
Flare	40.5
Missed-Approach Azimuth	6.75
Missed-Approach Elevation	6.75
360° Azimuth	6.75

j. A ground-radiated angle test signal is transmitted which may be used by receivers for an end-to-end check in a receiver test mode.

k. An unmodulated signal is transmitted in the preamble which may be used by receivers for automatic selection of the strongest received signal if more than one aircraft antenna is used.

l. Special out-of-coverage indication (OCI) signals are transmitted by approach and missed-approach azimuth systems to eliminate improper flag action when flying outside the system coverage sector.

1.3 System Configuration

1.3.1 Ground Subsystem

The signal format allows a large variety of compatible system elements to be installed in a given facility. The U.S. currently has identified three major configurations (combinations of elements) to satisfy the range of requirements. These are: (a) basic, (b) expanded, and (c) small community (see figure A-4). The small community and expanded configurations are functionally identical to the System A and System B configurations defined by AWOP for use in the system assessment. Additionally, TRSB can be realized in designs suitable for special applications, including man-transportable, shipboard, and special purpose equipments using alternate format possibilities.

a. The basic configuration consists of the following functional subsystems:

(1) Approach azimuth, nominally located on the runway centerline beyond the stop end.

(2) Approach elevation, nominally located beside the runway near touchdown.

(3) DME transponder, nominally located beside the azimuth equipment.

b. The expanded configuration consists of all the basic subsystems plus the missed-approach and flare subsystems. The expanded configuration is designed with full redundancy to meet all the operational requirements of ICAO and all Category III requirements.

c. The small community configuration meets the need for a minimum service system and consist of:

(1) Approach azimuth

(2) Approach elevation

(3) DME or ICAO standard marker beacons.

This equipment is designed to meet Category I requirements in a cost-effective manner and does not have all the redundancy features needed for higher category all-weather operations.

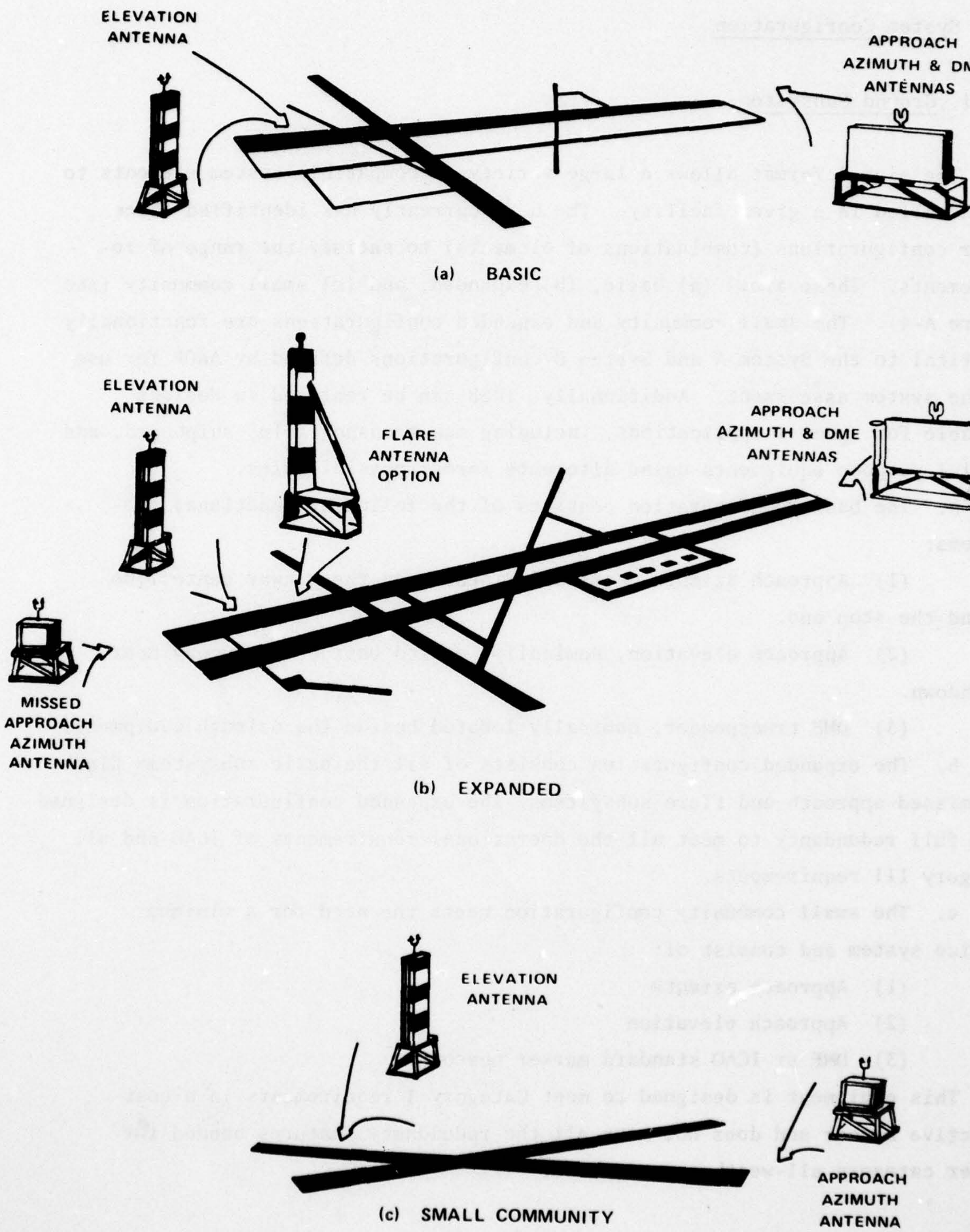


Figure A-4. Examples of Typical Ground Configurations

1.3.1.1 Angle Guidance Equipment

The U.S. proposal to ICAO describes several ground antenna design variants that satisfy the requirements of the new approach and landing system. Antennas using microwave optics such as the Rotman Lens antenna, are described to point out the feasibility of this type of implementation. In addition, antennas using the phased array principle are also provided. Systems using these variants have been built and tested to illustrate the approaches that are open to future providers and users of TRSB hardware. The test data that has been obtained on both of these antenna design alternatives confirms their appropriateness for MLS.

The basic simplicity of the TRSB ground station is revealed by the relatively few components required to transmit the signal-in-space and results in high reliability, high system availability, and low cost. The principal hardware elements are summarized in the following paragraphs and detailed in Section 2 of the U.S. proposal. Conventional circuitry and the extensive use of digital techniques throughout the design results in a highly stable signal-in-space. The major equipment modules associated with each guidance function are a transmitter, Executive Control Unit (ECU), antenna, and monitors.

The transmitter generates the appropriate C-Band signals and consists of a low power C-Band source, a DPSK modulator (one bit phase shifter), and a power amplifier. The entire design is a broadband requiring only a change in oscillator frequency to change channels. The only difference between transmitters for different ground facilities involves the size of the power amplifier. Shorter-range capability is provided using solid-state power amplifiers and full 20 nautical mile range service is currently provided using TWT amplifiers. Since the capability of higher power solid-state sources is advancing quickly it is very likely that all TRSB transmitters will use high reliability, solid-state amplifiers in the near future.

The ECU provides: (a) the timing cicuits to sequence the ground facility in accordance with the TDM format, (b) the intersite synchronization, and (c) the interface for the input and display of the digital auxiliary data signals. An ECU is included at each ground facility to permit continued operation even in

the event of the loss of inter-site synchronization. The implementation is based exclusively on digital circuit design using low-cost general purpose microprocessors.

1.3.1.2 Antenna System

The antenna system offered by the U.S. for detailed AWOP evaluation employs phased array technology. These phased arrays are controlled by a beam steering unit (BSU) using digital circuits to generate the commands for each phase shifter. The BSU design is modular such that any antenna beamwidth is accommodated by replacing printed circuit cards. The ground antennas of each system configuration differ only in the design of the antenna's radiating aperture. All azimuth antennas employ waveguide column radiators to provide sharp lower edge cut-off (typically 8 dB per degree) which minimizes ground interaction. Elevation antennas employ a passive coupling network to minimize the required number of phase shifters and maximize low angle performance.

All the TRSB phased arrays inherently provide a "fail-soft" characteristic which enhances system availability. That is, the parallel nature of these arrays provides inherent redundancy and; therefore, they experience insignificant degradation from a number of independent component failures. All the arrays are enclosed in weather proof radomes and maintained in a stable environment of air conditioning and dehumidification. Where required, the formation of ice on the radome is prevented by using heaters imbedded in the radome.

Waveguide column radiators are used to provide the sector antennas which transmit the preamble, auxiliary data, and out-of-coverage (OCI) signals for all azimuth and elevation ground facilities.

1.3.1.3 Monitoring

Executive monitoring in TRSB is performed using a combination of internal, integral, and field monitoring to ensure the integrity of the signal-in-space. The internal monitors check system synchronization, channel frequency, and data channel frequency stability, the data channel message accuracy, and transmitter power level. The integral monitor consists of a coupled waveguide

manifold to check the accuracy of the angle code and provide for the detection and location of an individual component failure in the parallel phased array structure. The field monitor provides an independent check on the accuracy of the angle code and on the power level of the data and angle guidance signals. By advancing the starting phase of all phase shifters at the beginning of each undirectional scan, the integral and field monitors continuously examine the coding accuracy throughout the MLS coverage volume. The detectors for the internal and integral TRSB monitors are integrated with the equipment design and the detectors for the field monitor are installed in the near field of the antenna. Monitoring decision making is performed in the microprocessor in the ECU. Maintenance monitoring is included to facilitate rapid isolation and field replacement of faulty equipment modules to the "line-replaceable-unit" (LRU) level.

1.3.2 Airborne Subsystem

The TRSB airborne subsystem consists of an antenna, an angle receiver-processor, a DME and certain controls and displays. Users may select the avionics components to satisfy individual requirements. At one extreme, a user may choose only an omni antenna and an angle receiver-processor for use with existing ILS displays; at the other extreme, a user equipped for Category III would select a redundant set of angle receiver-processors and DME Interrogators operating with existing or advanced displays.

Provision is made for the use of multiple aircraft antennas; during the dedicated time slot in the preamble, signal level sensing circuits automatically select the antenna receiving the strongest signal.

The angle receiver is a conventional double conversion superheterodyne receiver providing 200 channels. A log amplifier and a DPSK demodulator are included in the final IF stage.

The processor is built around microprocessor technology. The processor decodes the DPSK data to determine the function being received, digitizes the log video angle guidance signal, tracks the largest consistant TO-FRO signals, and interfaces with the output controls and displays. The processor includes extensive signal acquistion and track validation test features which ensure

that the angle guidance signal has the highest integrity and immunity in the presence of strong multipath and other forms of interference. Output angle guidance granularity is less than 0.005 degrees. The receiver-processor employs automatic self-test using built-in test equipment (BITE) and includes the capability for an end-to-end check of the complete unit by injecting a TRSB signal at the receiver input.

The DME interrogator can be configured as a separate unit. Operation is similar to conventional L-Band DME with wideband/narrowband processing to obtain the required accuracy. In addition, first pulse tracking and self-thresholding techniques are employed to minimize the effect of multipath (echos).

The Angle Receiver-Processor, built and tested during the U.S. development program, is housed in a short 3/8 ATR case with an associated mounting tray. Rear connectors provide input-output terminals and RF connectors which mate with the shockmount connectors. Front panel monitors and test switches provide a complete range of fault indications. A self contained bench test unit was also developed which permits the convenient check-out of the overall functioning of the receiver including its performance in multipath environments.

The angle receiver functions are controlled by the Angle Receiver Control Panel. Selections provide for frequency channel, azimuth angle, elevation (glide slope) angle, and indicator test selection. The Control Panel and Auxiliary Data Display Panel are identically constructed in a standard airline-type housing and are intended for front panel insertion and removal.

Output guidance signals from the angle receiver can be coupled to conventional CDI or ILS deviation indicators and an automatic flight control system. Auxiliary information displayed on the auxiliary data display panel includes: runway azimuth, facility identification, landing category, runway identification and condition, and the minimum usable glide slope for the particular runway.

The DME built and tested in the U.S. development program is housed in a standard short 1/2 ATR configuration. "On-off" and "standby" selections are controlled by the MLS control panel. Channel control is usually shared with a VOR-type control head.

Fourteen airline-type receiver-processors and associated precision DME's were produced in the U.S. development program and installed in a wide variety of aircraft, some of which were outfitted with automatic flight control systems. In addition, four receiver-processors configured for general aviation use were produced, and development is continuing on a low-cost configuration to illustrate that the TRSB concept can be implemented in a very economical simple version that is well suited to high volume production.

1.4 Supporting Data Base

An extensive data base is available with the scanning beam technique and the time reference format as a result of the U.S. and Australian MLS programs. Experience from these programs verifies the major features of the proposed TRSB system and the technology required for its implementation.

The U.S. experience with scanning beam techniques includes extensive testing, during the early 1960's, of autoland on REGAL and Flarescan systems, tests of the AILS system, siting sensitivity tests on the SITESCAN, V/STOL tests on the MODILS, and COSCAN. In addition, a large amount of testing and operational experience has been performed on tactical transportable systems utilizing scanning beam techniques. With MODILS operating on a time reference basis at C-Band and the other systems at Ku-Band, the applicability of technology and the concept in both frequency bands has been demonstrated.

Under the MLS program started in 1971, the U.S. has conducted an extensive series of flight tests, analyses, and simulations to verify conformance with the ICAO Operational Requirements. The field tests included performance measurements of the individual functional elements of the system and operational tests to validate system interfaces and demonstrate the operational utility of the TRSB signal-in-space.

In addition to the large aperture Test-Bed system (ICAO System B) on which the bulk of the TRSB data base was gathered, five smaller aperture systems were produced in order to validate cost and performance estimates of TRSB systems over the full range of capabilities and to explore diverse antenna implementations appropriate to various national requirements.

The U.S. program has demonstrated that the system proposed to ICAO (1° beamwidths) has instrumental accuracies well within the ICAO requirements for the most capable system; has superior performance at low heights; and is highly resistant to multipath effects. Tests of smaller aperture systems show a very gradual accuracy degradation as a function of beamwidth in conformance with theoretical predictions. However, even the 3° beamwidth system displays centerline accuracies within the "most capable" ICAO requirement and meets the U.S. accuracy requirement for automatic landings. Continuing development of precision L-Band DME has resulted in field test data with 2-sigma accuracies of less than 50 feet at two different test sites.

The TRSB receiver-processors have demonstrated practical implementations for rapid signal acquisition and validation which are effective over the full range of multipath conditions. In-beam multipath effects have been successfully reduced by motion averaging techniques in the avionics.

The extent of testing on specific equipment configurations developed in the U.S. and the completeness of the associated evaluation program have resulted in full assurance that the performance of all functions can be achieved as described in the system proposal.

1.5 International Availability

In considering the selection of a new system for international standardization, the Member Status of ICAO must be assured that the system chosen will be readily available for worldwide use and that procurement of the system will not be encumbered by patent rights (or other proprietary rights) held by any exclusive group. From its inception, the U.S. MLS program has fully appreciated and accepted the sensitivity toward the patent issue. In its dealing with development contractors, the U.S. has made certain that ICAO objectives will be met.

Patent clauses in MLS developmnet contracts, as well as policy direction to U.S. contractors with respect to involvement of industry outside the U.S., provide full assurance that TRSB equipment can come from many commercial sources throughout the world and will be available on a timely and economical basis.

1.5.1 Patent, Licensing, and Reproduction Rights

1.5.1.1 Patents

The U.S. MLS contractors must inform the U.S. Government of all inventions made during the course of the development work. The U.S. Government has arranged with these contractors for licenses to be made readily available to manufacturers in other countries where these inventions are patented.

1.5.1.2 Rights to Data

The U.S. Government recognizes the need for transferring technology and making available such material as performance data, technical manuals, and drawings for the internationally accepted civil aviation system. The U.S. Government has retained the legal right to all such material and will take suitable measures to make it available internationally.

1.5.1.3 Licensing

The manufacturing expertise a contractor has accumulated during his development work is something that cannot be assigned to the Government, since it would have no meaning in the context of transferring a discrete body of information. The contractors are free to make their own commercial arrangements for the transfer of such technology. Indeed, the U.S. Government has strongly encouraged its MLS contractors to make such licensing arrangements so that manufacturing sources for the TRSB MLS will be available throughout the world.

1.5.2 Potential for Timely Production

The U.S. Program for MLS development has given full attention to all aspects of assuring free use of technical information on a worldwide basis. It is the U.S. position that if ICAO selects TRSB, all ICAO signatory States can have ready access to the technical data and will be in a position to establish production sources in their countries, if they so desire.

The basic technology of microwave scanning beam systems has been under development in the U.S. for a period in excess of 15 years. Experimental scanning beam systems existed in 1958 and by 1965, full systems were under field evaluation. Many contractors in the U.S. participated in these early programs, and such widespread actvitiy has created a reservoir of technical talent. The legal rights to all data which the U.S. Government has retained will assure that a free international marketplace exists.

1.6 Proposal Organization

Part 1 of the U.S. proposal provides a detailed description of the proposed system, including the signal-in-space (signal format), a description of typical implementations, and a summary of the analyses and test data obtained during the most recent development program. Appendices A and B to Part 1 describe the TRSB test program and document the extensive TRSB data base respectively. Appendices C and D present the results of the supporting analytical verification programs and describe the statistical analysis methodology used to analyze the test data. A comparison of performance with the ICAO Operational Requirements is provided in Part 2. Part 3 contains proposed ICAO Annex 10 Standards and Recommended Practices (SARPS). Part 4 presents Guidance Material for Annex 10.

The ability to describe the proposed system precisely is a good indication that TRSB is sufficiently mature in its state of development to be suitable for international standardization.

APPENDIX B. ABBREVIATIONS

ACLS	Automatic Carrier Landing System
AD	Advanced Development
AEEC	Airline Electronic Engineering Committee
AFB	Air Force Base
AFCS	Automatic Flight Control System
AIA	Annual Instrument Approaches
AILS	Advanced Integrated Landing System
ALPA	Airline Pilots Association
ANC	Air Navigation Commission
AOCI	Airport Operators Council International
AOPA	Aircraft Owners and Pilots Association
ARINC	Aeronautical Radio Incorporated
ATA	Air Transport Association of America
ATC	Air Traffic Control
AWO	All Weather Operations
AWOD	All Weather Operations Division
AWOP	All Weather Operations Panel
CTOL	Conventional Take-off and Landing
CY	Calendar Year
DME	Distance Measuring Equipment
DOD	Department of Defense
DOT	Department of Transportation
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FM	Frequency Modulation
FPI	Flight Profile Investigations
FY	Fiscal Year
HUD	Head-Up Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IGIA	Interdepartmental Group on International Aviation

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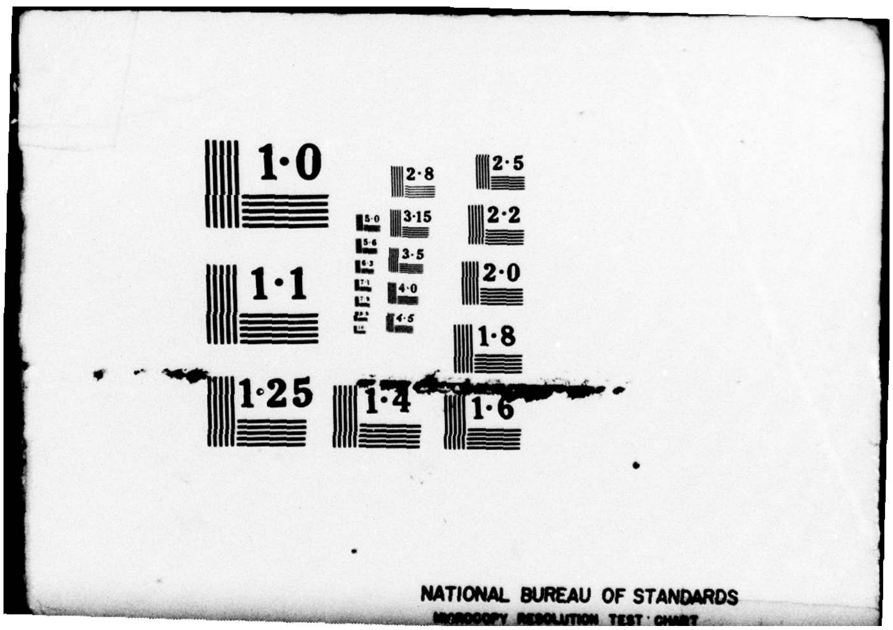
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ILS	Instrument Landing System
JTMLS	Joint Tactical Microwave Landing System
MLS	Microwave Landing System
MODILS	Modular Instrument Landing System
MRAALS	Marine Remote Area Approach and Landing System
NAFAG	NATO Air Force Armaments Group
NAFEC	National Aviation Facilities Experimental Center
NALF	Navy Auxiliary Landing Field
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATC	Naval Air Test Center
NATO	North Atlantic Treaty Organization
NAVCON	Navigation/Control
NBAA	National Business Aircraft Association
NIAG	NATO Industrial Advisory Group
NRL	Naval Research Laboratory
OR	Operational Requirements
PM	Program Manager
R&D	Research and Development
RFP	Request for Proposal
RNAV	Area Navigation
RTCA	Radio Technical Commission for Aeronautics
SARPS	Standards and Recommended Practices
SC-117	Special Committee No. 117 of the RTCA
SC-125	Special Committee No. 125 of the RTCA
SRDS	Systems Research and Development Service
STEP	Service Test and Evaluation Program
STOL	Short Take-Off and Landing
T&E	Test and Evaluation
TCV	Terminal Configured Vehicle
TACAN	Tactical Air Navigation

TRSB	Time Reference Scanning Beam
TSC	Transportation Systems Center
UHF	Ultra High Frequency
U.K	United Kingdom
U.S.	United States
USAF	U.S. Air Force
USMC	U.S. Marine Corps
USN	U.S. Navy
VHF	Very High Frequency
VORTAC	VHF Omni-Directional Range/Tactical Air Navigation
V/STOL	Vertical and Short Take-Off and Landing
VTOL	Vertical Take-Off and Landing
WG-A	Working Group A (of AWOP)
WPAFB	Wright-Patterson Air Force Base